

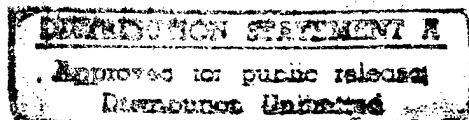


**U.S. Army Corps  
of Engineers  
Walla Walla District**

# Ice Harbor Lock and Dam Lake Sacajawea, Washington

## Feature Design Memorandum No. 34

### Spillway Deflectors



19970403 016

## September 1996

CONFIDENTIAL

**QUALITY CONTROL/QUALITY ASSURANCE CERTIFICATION**

**Ice Harbor Dam  
Feature Design Memorandum No. 34  
Spillway Deflectors  
6 September 1996**

**DISTRICT CERTIFICATION**

I hereby certify that the technical review process for the Ice Harbor Dam - Feature Design Memorandum No. 34 - Spillway Deflectors has been completed, and all technical issues have been resolved. The document is in compliance with applicable laws, regulations, and sound acceptable technical practices of the disciplines involved.

Bruce Collier  
Review Team Leader

9 September 96  
Date

SP [Signature]  
Chief, Engineering Division

9/12/96  
Date

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# ICE HARBOR LOCK AND DAM

## DESIGN MEMORANDUMS

<u>NO.</u>	<u>TITLE</u>	<u>COVER DATE</u>
1	Preliminary Design Report, Powerhouse General Plan and Detailed Cost Estimate Supplement 1 to D.M. 1	December 1959 31 October 1952 5 August 1955
2	First-Step Cofferdam and Access Facilities	23 January 1956
3	Powerhouse and Fish Pumping Plant (2 Volumes)	1 February 1956
4	Part 1 - South Shore Permanent Fish Facilities	Not Submitted
	Part 2 - North Shore Fish Facilities	15 July 1959
4.1	Deleted	
4.2	South Shore Visitor Facilities	30 August 1976
5	South Shore Nonoverflow and Spillway Dam	7 June 1957
6	Concrete Aggregate Investigation	20 July 1956
7	Relocation of SP&S Railway	19 September 1956
8	Part 1 - Real Estate, Construction Area Supplement 1 to Part 1	17 August 1955 1 August 1956
	Part 2 - Real Estate, Flowage Area Supplement 1 to Part 2	5 November 1957 1 June 1961
9	Downstream Gaging Station	June 1960
10	Resident Engineer Office Building	26 June 1956
11	Water Supply	25 July 1956
12	Second-Step Cofferdam	10 June 1958
13	Navigation Facilities and North Nonoverflow Dam Letter Supplement 1, Letter for Equipment Comparison	24 November 1958
13.1	Navigation Approach Channels	22 January 1960
14	Right Abutment Embankment	24 November 1958
15	Landscaping and Grounds Development	27 February 1963
16	Embankment Protection, SP&S	28 February 1958
17.1	UPRR Relocation - Part I	8 October 1958
17.2	UPRR Relocation - Part II Supplement 1 - Relocation Realignment	10 March 1959 22 September 1969
18	Embankment Protection, NP Railway	9 July 1959
19	Staffing of Ice Harbor Project	12 April 1957
20	Permanent Warehouse	22 April 1958
21	Remote Operation of Spillway Gates	18 November 1958

ICE HARBOR LOCK AND DAM  
DESIGN MEMORANDUMS (Continued)

<u>No.</u>		<u>Cover Date</u>
22B	Public Use and Access Facilities	22 May 1961
	Supplement 1	19 March 1962
	Supplement 2, Part A	25 June 1963
	Supplement 2, Part B	9 July 1963
23	Foundation Grouting and Drainage	22 October 1957
24	Reservoir Clearing	31 July 1959
25B	The Master Plan with Appendix 1	3 September 1963
25.1	Charbonneau Park	28 January 1969
	Letter Supplement 1, Modification of Water Supply System	19 January 1978
	Letter Supplement 2, Breakwater and Shoreline Protection	12 October 1978
26	Debris Disposal Facilities	19 May 1961
27	Navigation Lock; Upstream Floating Guide Wall	30 November 1960
28	Cost Allocation Studies	21 June 1961
29	Remote Control of Snake River Projects	7 September 1962
	Supplement 1 - Microwave Communications	23 October 1962
	Supplement 2 - Communications System	22 January 1965
30	Navigation Lock Fire Protection System	23 May 1962
31	Preliminary Design Report, Powerplant Units 4-6	March 1968
32	Permanent Juvenile Fish Facilities	April 1993
33	Navigation Lock Downstream Gate Replacement	February 1995
34	Spillway Deflectors	September 1996

## ICE HARBOR LOCK AND DAM

### LAKE SACAJAWEA, WASHINGTON

#### PERTINENT DATA

##### GENERAL

River mile	9.7
Drainage area, square miles	109,000
Normal hydraulic height, feet	100
Maximum structural height, feet	208
Overall length at crest, feet	2,790
Discharges, cfs	
Minimum of record (1958)	6,600
Mean annual	48,840
Standard project flood	409,000
Maximum of record (1894)	409,000
Spillway design flood	850,000
First power on line	December 1961
Concrete, cubic yards	1,330,000
Reinforcing steel, pounds	50,000,000

##### ESTIMATED COST

\$167,623,479

##### RESERVOIR

Name	Lake Sacajawea
Length	31.9 miles
Average width	0.4 mile
Maximum width	1.0 mile
Normal pool elevation	440 feet msl
Minimum power pool elevation	437 feet msl
Maximum pool elevation (850,000 cfs)	446.4 feet msl
Surface area at elevation 440 (low flow)	8,375 acres
Storage between elevation 437 and 440 (low flow)	24,900 acre-feet

## ICE HARBOR LOCK AND DAM

### LAKE SACAJAWEA, WASHINGTON

#### PERTINENT DATA (Continued)

##### DAM

Powerhouse, overall length	671 feet
Spillway, total length	590 feet
Navigation lock, overall width	173 feet
Concrete nonoverflow sections:	
Navigation lock to spillway, length	154 feet
Spillway to powerhouse, length	40 feet
Powerhouse to south shore, length	560 feet
Earth embankments, length (right)	624 feet
Total length of dam	2,822 feet
Maximum height of concrete section	213 feet
Maximum height of abutment section	123 feet
Deck elevation	453 feet msl

##### POWERHOUSE

Number of hydro-generating units:	
Initial installation	3
Ultimate installation (current operating units)	6
Turbines:	
Type	Kaplan
Number of blades	6
Synchronous speed	
Units 1 through 3	90 rpm
Units 4 through 6	85.7 rpm
Runner Throat diameter	
Units 1 through 3	280 inches
Units 4 through 6	300 inches
Plant discharge at rated head and output (6 units)	94,000 cfs
Total rated generator capacity at 0.95 power factor	603,000 kW
15% total overload generator capacity at 0.95 power factor	690,000 kW

ICE HARBOR LOCK AND DAM  
LAKE SACAJAWEA, WASHINGTON

PERTINENT DATA (Continued)

SPILLWAY

Type	Ogee, concrete gravity, gate controlled
Maximum width at base, elevation 304 feet msl	139 feet
Maximum height, foundation to deck	141 feet
Number of bays	10
Overall length, including piers	590 feet
Clear length	500 feet
Crest elevation	391 feet msl
Gate seal elevation	389.07 feet msl
Top of gate in closed position	442 feet msl
Deck elevation	453 feet msl
Gate lip elevation at maximum opening	436 feet msl
Type of gates	Tainter
Size of gates	52.9 feet high by 50.0 feet wide
Method of operation	Individual electric hoists
Spillway design flood:	
Peak discharge	850,000 cfs
Pool elevation	446.4 feet msl
Tailwater elevation	374.0 feet msl
Gross head	72.4 feet
Maximum flood at normal pool, elevation 440:	
Discharge	685,000 cfs
Tailwater elevation	370.5 feet msl
Gross head	69.5 feet
Maintenance closure spillway bays	Stoplogs

STILLING BASIN

Type	Horizontal floor
Width, perpendicular to flow	590 feet
Length, parallel to flow	168 feet
Floor elevation	304 feet msl
Baffles	1 row
Baffle size, H x L x W	8 ft. by 10.5 ft. by 10 ft.
Height of continuous end sill	12 feet

ICE HARBOR LOCK AND DAM  
LAKE SACAJAWEA, WASHINGTON

PERTINENT DATA (Continued)

NAVIGATION LOCK

Type	Single lift
Maximum lift (minimum pool McNary and zero discharge Ice Harbor)	105 feet
Inside length	675 feet
Inside width	86 feet
Normal minimum depth over lower sill (T.W. elevation-337)	16 feet
Minimum depth over upper sill (minimum pool)	15 feet
Normal depth over upper sill (normal pool)	18 feet
Upstream lock gate (radial) height	25 feet
Downstream lock gate (vertical lift) height	91 feet
Normal filling time	11 minutes
Normal emptying time	14 minutes

FISH PASSAGE FACILITIES

Width of ladders:	
North	16 feet
South	24 feet
Number of weirs (including orifice - control section)	103
Overflow weirs:	
Number	97
Height	6 feet
Orifice size:	
North	18 x 18 inches
South	21 x 23 inches
Slope:	
North	1 on 10
South	1 on 16
Exit of ladder, invert elevation	431 feet msl
Entrance of ladder, invert elevation	332 feet msl
Normal fishway flow (from forebay):	
North	74 cfs
South	142 cfs
Auxiliary attraction water pumps:	
North	3
South	8

ICE HARBOR LOCK AND DAM  
LAKE SACAJAWEA, WASHINGTON

PERTINENT DATA (Continued)

FISH PASSAGE FACILITIES (Cont)

Discharge per pump:

North	250 cfs
South	300 cfs

Fishway entrances (all 12 feet wide):

South	2
Nonoverflow	3
North	3

Powerhouse fish collection system:

Number of orifice entrances (2 feet x 6 feet)	12
Length of channel	661 feet
Width of channel	17.5 feet

## EXECUTIVE SUMMARY

### The Problem.

River flows passed through the spillways of the dams located on the lower Columbia and lower Snake Rivers produce water that is supersaturated with dissolved gases. These high levels of dissolved gases are detrimental to aquatic life. In the 1970's, spillway deflectors were installed on the spillways of several U.S. Army Corps of Engineers' projects (Bonneville, McNary, Lower Monumental, Little Goose, and Lower Granite Dams) to reduce the high levels of total dissolved gas (TDG) produced. However, in 1976, it was decided to postpone the construction of deflectors at Ice Harbor Dam. Key fishery researchers of that time judged that spillway deflectors at Ice Harbor Dam would cause poor hydraulic conditions in the tailrace that would likely delay or block adult fish passage. Also, the severity and frequency of TDG supersaturation downstream of Ice Harbor Dam was expected to be reduced significantly in the near future because of several factors. These factors included: 1) the recent completion of all six powerhouse turbines at Ice Harbor Dam, which would significantly reduce the amount of spill discharge required during periods of high flow; 2) the recently completed Dworshak Dam, having 3 million acre-feet of active flood control storage, which would also reduce the amount of spill required at Ice Harbor Dam due to high flows; and 3) the installation of spillway deflectors and the accelerated schedule for turbine installation at the three lower Snake River dams upstream of Ice Harbor Dam, which would reduce the frequency and level of TDG entering the forebay of Ice Harbor Dam in the near future. This reduction of TDG in the forebay was expected to reduce, to some extent, the level of TDG downstream of Ice Harbor Dam as well.

Operation of Ice Harbor Dam has changed in the past few years. Spill is currently used as a method of routing juvenile fish away from powerhouse turbines. Also, during high river discharges, greater quantities of spill have recently been required at Ice Harbor Dam because of turbine outages for servicing and repairs. These more frequent and higher levels of TDG have renewed interest in reducing TDG levels below Ice Harbor Dam. The importance of reducing TDG levels is emphasized by the rapid decline of returning adult salmon that has lead to the listing of several species as threatened or endangered under the Endangered Species Act.

### Possible Alternatives for Reducing High TDG Levels.

Concurrent with the preparation of this design memorandum, a separate dissolved gas abatement study was initiated that explored alternatives for reducing TDG levels downstream of the eight Federal dams on the lower Snake and lower Columbia Rivers. Several structural modifications as well as operational changes are being examined in this gas abatement study. The structural modifications include raising the stilling basin invert elevation only, raising the stilling basin invert along with

adding a deeper basin downstream of the raised basin (called a negative step stilling basin), installing spillway deflectors, and combinations of these modifications as well as other concepts. The findings of this study so far are presented in Dissolved Gas Abatement Study, Phase I, Technical Report, April 1996. The recommendation given includes the continuation of efforts to install spillway deflectors at John Day and Ice Harbor Dams. Some of the reasons given are the uncertainties of how effective other alternatives are in reducing TDG levels, the relative low cost of installing deflectors compared to the other alternatives, and the shorter timeframe required to implement spillway deflectors.

#### Effectiveness of Spillway Deflectors in Reducing High TDG Levels.

It is estimated that deflectors on the Ice Harbor spillway would reduce TDG levels by up to 5 to 10 percentage points (e.g., reduce TDG from 120 percent to 110- to 115-percent saturation). Even this small amount of reduction can have significant biological benefits. This estimated reduction is based on an extrapolation of data collected at Lower Monumental Dam (both before and after the addition of deflectors) to Ice Harbor Dam (the spillway design of these two dams are very similar). This maximum reduction is likely to occur for total spill discharges up to 60 thousand cubic feet per second (kcfs).

#### Concerns about Installing Spillway Deflectors at Ice Harbor Dam.

The previous Ice Harbor Dam model studies of 1976 examined river discharges of 160 kcfs and higher. Hydraulic conditions in the tailrace did not appear favorable for adult fish passage in the vicinity of the fishway entrances for these high discharges with spillway deflectors installed. However, information indicates that adult fish may actually hold up and delay migrating further upstream when Snake River discharges begin to exceed 150 kcfs. Current Ice Harbor Dam general model tests conducted at Waterways Experimental Station (WES) indicate that adult fish entrance conditions are adequate for river discharges up to 150 kcfs with deflectors installed on the center 8 spill bays.

Preliminary model tests indicated that fishway entrance conditions could be significantly improved by extending the north training wall. However, there is insufficient time to design and incorporate the training wall extension into the current plans and specifications for installing the eight spillway deflectors. These preliminary tests also indicate installing deflectors on spill bays 1 and 10, in conjunction with training wall extensions (see plates 1 and 2), may not adversely affect adult fish passage conditions while obviously reducing the TDG produced by these two spill bays. Further model testing to determine deflector elevation for the two end bays, to refine the training wall extension design, and to explore other options for improving tailrace conditions for adult fish passage are needed. Results and recommendations from these tests will be reported in a letter supplement to this design memorandum.

Movement of rock debris within the stilling basin was also addressed in the current Ice Harbor model studies. Rock debris can be pulled into the stilling basin by the hydraulic action of skimming flow produced by spillway deflectors. Significant erosion of the stilling basin has been found in two areas of the basin at Lower Monumental Dam. The erosion appears to be related to hydraulic conditions created by discharge through adjacent deflector and non-deflector bays. Unlike Lower Monumental, the Ice Harbor spillway has extended training walls that partially separate the end bays from the eight interior spill bays. Model tests of the Ice Harbor spillway indicate the existing training walls are long enough to prevent erosive activity of rock debris between a non-deflector bay to the outside of the training wall, and a deflector bay to the inside of the training wall. However, a potential for rock debris to be pulled into the basin in the vicinity of the training walls was observed in the model. Most of the debris pulled into the basin near the training walls migrated around the end of the wall to the toe of the adjacent deflector spill bay.

Ice Harbor stilling basin conditions, with deflectors on the eight interior bays, are better represented by conditions within the Lower Granite stilling basin than those which occur at Lower Monumental. Inspection of the Lower Granite stilling basin confirmed large rock debris was being brought into the basin by hydraulic action caused by the deflectors. The basin showed signs of some erosion; however, no major concentrated erosion zones were found. Though uncertainty exists on how this material would effect the basin during large, long duration spill events, the moderate spill conditions that have occurred at Lower Granite since construction in 1975 have not resulted in any major damage. Thus, debris concerns associated with the installation of deflectors at Ice Harbor are not such that construction of deflectors should be delayed given the serious need to reduce TDG levels at Ice Harbor. However, the basin should be monitored closely after any major spills and results of the Lower Monumental Stilling Basin Erosion Study should be reviewed for possible application at Ice Harbor.

Preliminary model investigations at WES indicate that installation of deflectors at Ice Harbor will result in higher cross channel velocities and greater surface turbulence near the end of the downstream navigation lock guidewall. These conditions are likely to make it more difficult for barge traffic to navigate into and out of the lock.

#### Recommendations.

This design memorandum recommends proceeding with the immediate installation of spillway deflectors on the center eight spill bays. It also recommends preparing a supplement to this design memorandum, which will address the issues relating to improving tailrace conditions for adult fish passage, improving navigation conditions, and the possible installation of deflectors on spill bays 1 and 10.

### Costs and Schedule.

The estimated construction cost of installing deflectors on the center 8 spill bays is \$6.8 million. Several construction dewatering schemes were identified by a value engineering study, which could save up to \$1.8 million. The contract documents are being written to allow the contractor to choose and design their own dewatering system. The contract is scheduled to be awarded by 15 July 1996 with a completion date of 15 March 1997.

The estimated cost of preparing the letter supplement addressing improvements for adult fish passage (including additional model testing) is \$300,000. The letter supplement is scheduled to be completed by the fall of 1996.

ICE HARBOR LOCK AND DAM  
SPILLWAY DEFLECTORS  
FEATURE DESIGN MEMORANDUM NO. 34

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Deflectors - Letter Report*, Preliminary October 1994
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## LIST OF ACRONYMS

Bi-Op	March 2, 1995, National Marine Fisheries Service Biological Opinion, Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years
CENPW	U.S. Army Corps of Engineers, Walla Walla District
cfs	Cubic feet per second
Corps	U.S. Army Corps of Engineers
CRiSP	Columbia River Salmon Passage Computer Model
DGAS	Dissolved Gas Abatement Study
EA	Environmental Assessment
ESA	Endangered Species Act
FGE	Fish Guidance Efficiency
fmsl	Feet mean sea level
FPE	Fish Passage Efficiency
fsp	feet per second
GBT	Gas Bubble Trauma
ICFWRU	Idaho Cooperative Fish and Wildlife Research Unit
kcfs	Thousand cubic feet per second
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NPE	North powerhouse entrance
NSE	North spillway entrance
PIT-tag	Passive Integrated Transponder
psf	Pounds per square foot
psi	Pounds per square inch
SDF	Spillway design flood
SHPO	Washington State Historic Preservation Office
TDG	Total dissolved gas
USFWS	U.S. Fish and Wildlife Service
WES	U. S. Army Corps of Engineers, Waterways Experiment Station

## SECTION 1.0 - INTRODUCTION

### 1.01. GENERAL.

Due to the rapid decline in salmon runs, regional fishery interests have requested a voluntary spill at eight Federal dams on the lower Columbia and lower Snake Rivers. They believe the voluntary spill will help improve juvenile salmonid fish passage around the dams. However, total dissolved gas (TDG) supersaturation occurs when water is spilled over the existing spillways. High levels of TDG can cause mortality in juvenile and adult migratory fish, resident fish, and other organisms. Dissolved gas control was also a regional issue in the late 1970's, and several of the eight Federal dams were retrofitted with spillway deflectors to reduce the level of high TDG supersaturation. These spillway deflectors were designed for involuntary spillway releases, which occur when river discharges exceed powerhouse hydraulic capacities. Ice Harbor Dam does not have deflectors on the spillway and is known to produce high TDG levels during spill operations.

### 1.02. PROJECT DESCRIPTION.

#### a. General.

The main structures of Ice Harbor Dam consist of a powerhouse, spillway, stilling basin, navigation lock, non-overflow sections, a rockfill embankment on the north shore, two adult fish ladders, and a newly constructed juvenile fish bypass system (see plate 1). All structures, except the new juvenile fish bypass system, were constructed during 1959-61.

#### b. Powerhouse.

The powerhouse structure houses six complete kaplan turbines and associated generators, an erection bay, service bay, control room, and project office space. Synchronous speed of the turbines is 90 revolutions per minute with a runner diameter of 280 inches. Each turbine will develop at least 143,000 horsepower at 89 feet of head.

#### c. Spillway and Stilling Basin.

The spillway at Ice Harbor Dam has a total length of 590 feet (including 9 intermediate piers) and consists of 10 gate-controlled spill bays, each 50 feet wide. Piers, 10 feet in width, separate the spill bays (see plate 2). Elevation of the spillway crest is 391 feet mean sea level (fmsl). Spillway discharges are controlled by 10 tainter gates, each 50 feet wide by 52.9 feet high. The design capacity of the spillway is 850 thousand cubic feet per second (kcfs) with a corresponding maximum pool elevation of 446.4 fmsl. At the normal full pool elevation of 440 fmsl, the spillway will pass a maximum of 685 kcfs. The energy of the water discharging through the spillway

is dissipated by a hydraulic jump and baffles in a horizontal apron-type stilling basin. One row of baffles (8 feet high, 10.5 feet long, and 10 feet wide) plus an end sill (12 feet high and 590 feet long) assists in dissipating the energy. The stilling basin has been designed to contain the jump for discharges up to 850 kcfs.

d. Navigation Lock.

The single-lift lock is located on the north side of the river. It has a clear inside (86 feet wide and 675 feet long). The maximum lift is 105 feet.

e. Adult Fish Ladders.

The adult fish passage facilities at Ice Harbor Dam consist of north and south shore fish ladders, a powerhouse collection system and transportation channel, and attraction water facilities. Total normal discharge through the ladders from the forebay is approximately 216 cubic feet per second (cfs) (74 cfs from the north ladder and 142 cfs from the south ladder).

f. Juvenile Fish Bypass System.

The new juvenile fish bypass system is currently under construction and consists of standard-length submerged traveling screens, vertical barrier screens, raised intake gates, fish orifices, fish collection channel, dewatering system, and fish transportation system. A fish sampling system is also being constructed to allow evaluation of the juvenile fish bypass systems.

1.03. PURPOSE.

This design memorandum was prepared in response to the March 2, 1995, National Marine Fisheries Service Biological Opinion, *Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years*, Reasonable and Prudent Action, measure 18. This measure directs the U.S. Army Corps of Engineers to reduce gas levels with appropriate structural modifications (i.e., spillway and stilling basin modifications) contingent upon the results of gas abatement evaluations in 1995 and 1996. The *Dissolved Gas Abatement Study (DGAS), Phase I*, Technical Report (April 1996) supports installation of spillway deflectors at Ice Harbor Dam.

A U.S. Army Corps of Engineers, North Pacific Division letter, dated 12 June 1995, directed the U.S. Army Corps of Engineers, Walla Walla District to immediately begin design of spillway deflectors at Ice Harbor Dam. This design memorandum recommends a method for implementation of spillway deflectors that will provide some reduction in TDG production until a better structural solution is identified through the on-going DGAS. Because this design memorandum is not a feasibility study, review of other alternatives are not provided in detail, but are referenced for

completeness and consistency with the preparation of the Environmental Assessment required under the National Environmental Policy Act.

#### 1.04. SCOPE.

This design memorandum provides background information on the physical production and biological effects of TDG. It identifies several alternatives that may reduce TDG supersaturation levels, including an operational measure and other structural modification measures derived from the on-going DGAS. Alternatives are described and evaluated from available information, including current hydraulic model study information.

This design memorandum recommends the construction of spillway deflectors at Ice Harbor Dam and presents design, construction, and environmental compliance information related to this recommendation. While not viewed as a total fix to the TDG production, deflectors can provide an estimated interim reduction in TDG of 5 to 10 percent, until a better solution is found.

#### 1.05. AUTHORIZATION.

This design memorandum is an element of the Columbia River Salmon Mitigation Analysis and is being conducted under the existing authority for Ice Harbor Dam. That authority is the Rivers and Harbors Act of 1945, Public Law 79-14, dated 2 March 1945.

#### 1.06. PREVIOUS STUDIES AND REPORTS.

Studies have previously been completed concerning spillway deflectors at Ice Harbor Dam. The studies and report titles are listed below:

- a. *Ice Harbor Spillway Deflectors, Letter Report* (October 1994; preliminary).
- b. *Spillway Deflectors at Bonneville, John Day, and McNary Dams on the Columbia River, Oregon-Washington and Ice Harbor, Lower Monumental, and Little Goose Dams on the Snake River, Washington. Hydraulic Model Investigation, Technical Report Number 104-1, 1984.*
- c. *Ice Harbor General Spillway Model, Deflector Study, Report No. 1.* U.S. Army Corps of Engineers, North Pacific Division Hydraulic Laboratory, 23 August 1976.
- d. *Dissolved Gas Abatement Study, Phase I, Technical Report.* U. S. Army Corps of Engineers, Portland and Walla Walla Districts, April 1996.

## SECTION 2.0 - BACKGROUND

### 2.01. TOTAL DISSOLVED GAS (TDG) SUPERSATURATION.

Spill through the lower Snake River dams causes TDG supersaturation that can exceed state water quality standards, as well as the Federal water quality criteria (110 percent of barometric pressure). Water passing through the spillways of the dams entrains air (in the form of bubbles) as it passes under the tainter gates, over the spillway, and plunges into the stilling basin. The air bubbles are forced into solution by hydrostatic pressure, thus raising the TDG concentration in the water. As a convenience, dissolved gas pressures may be expressed as a percentage of barometric pressure (percent saturation). Total dissolved gas supersaturation is often mislabeled as "nitrogen supersaturation" because nitrogen was believed to be the principle gas that caused problems.

Nitrogen, oxygen, and argon comprise about 78, 21, and 1 percent, respectively, of the elemental gases present in dry air. Under stable conditions, the pressure of every gas in the atmosphere reaches an equilibrium with its dissolved form in water. At this point, the water is said to be saturated. Stable conditions being unusual, water is rarely at equilibrium with atmospheric gases. Rather, it is either under-saturated or over-saturated (supersaturated) with atmospheric gas(es).

Spill discharge rate is the dominant variable explaining the variation in TDG concentrations in a specific tailrace and for the next downriver reservoir. Other variables determining TDG supersaturation include stilling basin water depth, total river discharge, downstream mixing potential between powerhouse and spillway discharges, water temperature, and oxygen:nitrogen ratios.

Water temperature and pressure, as a function of depth, are important factors in determining gas solubility. The capacity of a body of water to hold dissolved gas is inversely related to temperature. Increasing the temperature of a volume of water decreases the volume of gas it will hold at equilibrium. Therefore, an increase in water temperature alone will produce supersaturation in water that is initially saturated at 100 percent (Weitkamp and Katz, 1980). Pressure is increased in water by hydrostatic head. Hydrostatic pressure increases rapidly with depth, thus greatly enhancing the capacity of deeper water to dissolve and hold gases.

Dissolved gases are remarkably stable despite their supersaturated condition and, once the water is supersaturated, it tends to stay supersaturated. This happens because the diffusion pressure gradient and surface-to-volume ratio are usually low, and the water's surface tension is high. Because dams slow and quiet the water, the dissolved gases usually do not equilibrate with the atmospheric air between dams. Consequently, supersaturation conditions can persist and accumulate over extended

distances (Ebel, 1969; Corps, 1992). An overview of the relationship of gas laws and water can be found in Colt (1984).

## 2.02. PROJECT OPERATION.

### a. System-Wide Operations - Late 1970's and 1980's.

Spill has been an integral part of the "spread-the-risk" system-wide operation coordinated regionally in the late 1970's and 1980's. This operational philosophy was based on the capability of the juvenile fish transportation program to 1) collect and barge 50 to 60 percent of the smolts arriving at Lower Granite Dam, 2) either barge or bypass 60 to 70 percent of the smolts arriving at Little Goose Dam, and 3) since 1993, either barge or bypass 60 to 70 percent of the smolts arriving at Lower Monumental Dam.

Assuming that all fish at Lower Granite and Little Goose Dams collected prior to 1993 were transported and not bypassed back to the river (as regulated by flow dependent triggers in the Annual Fish Passage Plans), this left about 10 to 12 percent of the total original Snake River smolt population arriving at Lower Granite Dam to migrate in-river to Ice Harbor Dam. In-river flows were prioritized for hydropower generation under the 1970 to late 1980 operations, utilizing maximum turbine operation with only short periods of forced spill occurring during high flow years. These short duration, forced high-spill periods typically last only a few weeks. If these operations produced up to 120 percent TDG, then up to 100 percent of that spilled proportion (of the 10- to 12-percent population segment actually passing Ice Harbor Dam for those few days) could have been negatively affected with gas bubble trauma (GBT). If the river water was above the lethal TDG threshold of 120 to 127 percent, GBT could have manifested into mortality.

### b. Current and Probable Future System-Wide Operations.

The 1994 NMFS/U.S. Fish and Wildlife Service (USFWS) emergency spill operation for spring chinook and the spill volumes requested in the March, 2, 1995, National Marine Fisheries Service Biological Opinion, *Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years* (Bi-Op) are representative of a total system-wide spill operation. The operation was designed to enhance in-river passage of smolts through reductions in travel time and collection for barge transport. The Bi-Op requests that the percent of total river flow needed to achieve an 80-percent fish passage efficiency (FPE) should be spilled at Ice Harbor Dam. This has been calculated to be 27 percent for spring passage and 70 percent for summer passage for 24 hours, based upon fish guidance efficiency (FGE) estimates calculated for the ice-and-trash sluiceway and through Passive Integrated Transponder (PIT)-tag analyses. These estimates may be modified based upon the submerged standard-length screens installed at Ice Harbor Dam in 1993. The gas production qualities of these percent spill

flows are highly dependent upon total flow in the river, in that as total river flow increases the same percentage of spill applies to the FPE equation resulting in a proportional increase in spill volume. But, percent TDG production is highly dependent on spill volume. The ability to achieve the 80-percent FPE becomes diminished as total river flow increases due to the constraint of holding spill volume below the 25 thousand cubic feet per second (kcfs) cap that produces 120-percent TDG. This is measured in the tailrace according to the conditions of temporary water quality waivers issued by Oregon Department of Environmental Quality and Washington Department of Ecology.

Currently, the powerhouse turbines are operated during the juvenile fish migration season within 1 percent of peak efficiency. This has occurred because of the assumption that juvenile fish survival through the turbines is greater if the turbines are operated near peak hydraulic efficiency. This limitation translates to a maximum powerhouse flow capacity of about 88 kcfs, which is equivalent to about 4.5 turbines at maximum capacity instead of 6 turbines. (Maximum powerhouse discharge capacity is about 105 kcfs if the 1-percent peak efficiency limitation is not imposed.)

It was envisioned in 1976, when deflectors were installed on most lower Snake River spillways, that all available turbine units would be operated at or near full capacity in all future operations of Ice Harbor Dam, thus, highly restricting spill flow and maintaining an adequately high tailrace elevation. Since 1976, there have been times when, due to the lack of power demand, flows through powerhouse(s) had to be reduced and more flow was forced over the spillway(s). An example of this occurred during the high flow period of 1993, when the full flow of the lower Snake River was passed through the Little Goose Dam spillway at night because of low power demand. In a similar situation, high spill can also occur due to maintenance outages of turbine units, as happened at Ice Harbor Dam in 1995. Because of these high spills, dissolved gas supersaturation levels reached greater than 135 percent of saturation. In addition, turbines are not always available during the spring high-flow season because of long-term scheduled repair and maintenance or because of necessary unscheduled repairs.

In 1993, submerged traveling screens were installed in the turbine intakes at Ice Harbor Dam, and diverted fish were passed through 14-inch-diameter orifices into the ice-and-trash sluiceway. Prototype tests in 1987 at Ice Harbor Dam indicated FGE of about 78 percent for spring chinook salmon and 93 percent for steelhead (Brege *et al.*, 1988). Despite achieving the FPE goal of 80 percent using these FGE values for the calculation, NMFS required the U.S. Army Corps of Engineers (Corps) to spill up to 25 kcfs nightly from 1800 to 0600 hours, 15 April through 31 July. This was because PIT-tag derived FGE values were substantially lower, near 55 to 64 percent. Voluntary spill for juvenile fish passage was limited to 25 kcfs to maintain dissolved gas levels below 120 percent of saturation. The stated reason for exceeding the FPE target was that the ice-and-trash sluiceway outfall was an inadequate passage route exit. Despite exceeding FPE, similar spill levels were required for the 1994 and 1995 juvenile fish outmigrations with spring operations of 25-kcfs spill across 24 hours a day between 10 May and 15 June. In 1996, the ice-and-trash sluiceway will be closed due

to the operation of the completed juvenile facility, although surface bypass testing in 1995 indicates that surface skimming may provide the highest passage percentage. In addition, a suitable outfall will be in place for the juvenile fish outmigration. It does remain likely that substantial spill levels will again be required at Ice Harbor Dam in 1996 to achieve Bi-Op requested conditions between 15 April and 31 August and/or due to one or two turbine unit outages for repair or maintenance.

### 2.03. BIOLOGICAL EFFECTS.

Dissolved gas supersaturation in the Snake River can lead to the development of "gas bubble disease," as originally described by Marsh and Gorham (1905), or, as termed later, gas bubble trauma by Alderdice and Jensen (1985). The impacts of supersaturation can range from changes in behavior to mortality, by bubbles forming in and on the bodies of aquatic organisms (Bouck, 1980).

Fish, amphibians, and aquatic invertebrates can develop gas bubbles in their organs and tissues (emphysema) and/or in their vascular systems (emboli). The condition can produce a variety of signs and physiological changes that can often be fatal, but not necessarily evident upon external examination. As early as 1900, these effects were described in fish (Gorman, 1900; and Marsh and Gorham, 1905). Boyle (1942) then produced these same effects experimentally in fish. These authors described external signs in fish as bubbles located in the fins, along the lateral line, and in the lining of the mouth. Internally, bubbles were found within the blood vessels and behind the eyes, causing exophthalmia (pop-eye). Gas emboli in blood may vary in size and may block various-sized blood vessels, thereby impacting multiple parts of the body. In extreme cases, emboli can block blood flow through the heart, resulting in death. Death may occur from GBT at TDG levels as low as 103 percent of barometric pressure in shallow water (Colt *et al.*, 1986). The maximum safe level for free-swimming organisms in the field remains a much debated issue, although the Federal and state water quality standards aim to control TDG below 110 percent.

Adult salmonids are physiologically more susceptible to the effects of TDG supersaturation than juveniles due to their more developed organs (White *et al.*, 1991). One of the early reports of GBT was made by Westgard (1964). He reported that a 119-percent saturation produced blindness from GBT in 34 percent of the adult spring chinook salmon in the shallow McNary spawning channel in 1962. Blinded adults had difficulty spawning with a pre-spawning mortality rate that was 82 percent higher than fish that were not blinded. Blindness and/or cranial blistering (referred to as head burns or scalping) on adult salmonids occurred at Snake River dams immediately following the peak duration of forced spill during the high spring flows of 1993. Bjornn *et al.* (1994) outfitted 1,181 adult spring chinook salmon with radio transmitters at the John Day trap and recaptured 255 of these at Lower Granite Dam. They were examined for tags, marks, and injuries. None of the spring chinook had external signs of GBT or "head burns" when captured, tagged, and released from John Day Dam. At Lower Granite Dam, 24.3 percent (62 of 255) of the adult chinook salmon outfitted with

transmitters had some degree of cranial blistering following less than 15 days exposure to supersaturated water.

Concern for gas supersaturation in the Columbia Basin has a long history associated with spill at the hydroelectric dams. The first evidence of a TDG supersaturation problem in the Columbia River system was documented shortly after Bonneville Dam became operational. There were reports of dead adult salmon prompting several investigations by the Corps and the various fishery agencies. Westgard (1964) observed chinook salmon suffering from gas bubble disease at the McNary Spawning Channel in 1962. In the mid 1960's, it gradually became evident that a TDG problem existed in the Columbia River system (Weitkamp and Katz, 1980). The seriousness of the situation was not widely accepted until 1968 when the John Day powerhouse closed and supersaturation ranging from 120 to 140 percent killed an estimated 20,000 adult (sockeye and summer chinook) salmon (Beiningen and Ebel, 1970; Ebel, 1971).

When the GBT observations were extended to smolt survival (Ebel, 1969), the threat to salmon became a regional concern. In response, a Tri-State Governor's Task Force on Nitrogen Supersaturation was convened to address the problem. Flow deflectors were constructed on the spillways of five of the eight Federal dams on the lower Snake and Columbia Rivers as an interim measure to reduce TDG supersaturation during high flows until more turbines units could be installed system wide and basin storage could be increased.

The signs of GBT are not an easily demonstrated cause-and-effect relationship because many of the signs occur internally and disrupt neurological, cardiovascular, respiratory, osmoregulatory, and other multiple physiological functions (Fidler and Miller, 1994; White *et al.*, 1991; Weitkamp and Katz, 1980; and Stroud *et al.*, 1975). External bubbles can block the flow of respiratory water across the gills (Fidler and Miller, 1994; Jensen, 1980; and Shirahata, 1966). The GBT is believed to increase the susceptibility of fish to other stresses such as bacterial, viral, and fungal infections (Weitkamp, 1976; Nebeker *et al.*, 1976; Sniesko, 1974; and Meekin and Turner, 1974). Bubble growth in the vascular system was often cited as a principle cause of mortality in Columbia River studies (Weitkamp and Katz, 1980), but other symptoms (extra-corporeal bubbles in the gills and sub-dermal bubbles on the skin and mouth) were often present at the same time (Stroud and Nebeker, 1976, Stroud *et al.*, 1975; and Meekin and Turner, 1974). It remains unclear whether the various symptoms act in concert or appear due to different exposure regimes of increasing TDG concentrations.

Fidler and Miller (1994) and White *et al.* (1991) suggest that physiological and behavioral responses occur concurrent with achieving TDG concentration thresholds at principally two tiers according to magnitude and duration of exposure. White *et al.* (1991) tested the results of a literature review analysis (over 1,000 records) that suggested a lower mortality threshold occurs at a TDG supersaturation of 110 percent (1.1 atmospheres) while a higher mortality threshold occurs at 115 to 119 percent.

Results with adult rainbow trout indicated that the lower threshold (110 percent) is associated with a combination of sub-dermal bubble growth in the mouth and extra-corporeal bubble growth between the gill lamellae. The second phase of experiments included intravascular microscopic studies and confirmed the source of mortality for the lower threshold at a TDG supersaturation of 110 to 112 percent. The transition from a lower TDG threshold to an upper threshold involved a shift in the bubble-related mechanisms that lead to death. At the lower threshold, sub-dermal bubbles in the mouth lining and extra-corporeal bubbles in the gill lamella act to block the exchange of respiratory gases. At a TDG of 115 percent, the extra-corporeal bubbles were fewer and could even disappear, thus increasing the time to mortality. This is possibly due to larger bubbles being dislodged by respiratory water flow through the gills. At a TDG between 115 and 119 percent, intravascular bubble formation began, and time to mortality decreased with increasing TDG levels. At these higher threshold TDG levels, sub-dermal bubbles in the mouth lining were either smaller or absent. This observation indicates that the examination of only external symptoms for GBT in sample fish can be misrepresentative of the impact to the population. The rapid death caused by intravascular bubbles at these higher TDG levels may not allow time for sub-dermal bubbles to develop. This sequence to mortality, correlated with data from the literature, suggests that an observer may falsely conclude that some relief to the fish may occur if that observer only evaluates external symptoms during this transition from the lower to the higher threshold.

Although the existing database for the effects of TDG supersaturation on in-river migrating salmonids is far from complete, a reasonable amount of biological monitoring data on steelhead and spring chinook during the 1993, 1994, and 1995 Snake River hydro-operations has been compiled. Recent PIT-tag survival data suggest that sublethal impacts occur in juvenile chinook exposed to 12-hour spill plumes containing 115-percent TDG saturation. Lethal impacts occurred with acute exposure of +130-percent TDG below Ice Harbor Dam following 12-hour spill plume exposures containing 120-percent TDG saturation (Cramer *et al.*, 1996; NMFS memo authored by S. Smith, March 1996). Both physical and biological principles found in the literature are supported by these more focused analyses for 1995, although direct mechanisms remain untested. These analyses suggest that fish condition and maintained depth and rate of travel determine variable exposure histories. When these mechanisms are correlated with percent TDG thresholds, they can be substantial in the actual expression of the rate and magnitude of the effects of TDG supersaturation. However, smolts are subjected to changes in pressure from the changing water depths required to successfully pass through both submerged bypass and spillway routes. Although actual observation of GBT in juvenile salmonids within the 110- to 120-percent TDG saturation range is difficult to detect through visual inspection alone (thus eluding a direct cause-and-effect relationship to mortality), bubble formation in the vascular system and/or gill lamellae is well documented (Fish Passage Center weekly reports, 1993) and is typically present when mortality does occur (National Biological Survey-Cook shallow water experiments, M. Mesa, personal communication, Cook, WA, October 1995).

Laboratory bioassays conducted on juvenile brown and rainbow trout by White *et al.* (1991) indicated that no significant mortality occurred in the 112-percent supersaturation treatment, except during 2 tests when it exceeded 113 percent of barometric pressure. Their report suggests that a critical threshold exists between 113 and 117 percent of barometric pressure for juvenile trout. This is slightly higher than the initial threshold level (110 to 112 percent) identified in the physiology studies with adult trout. As the juvenile trout grew, they became more susceptible to a 125-percent TDG supersaturation. Juvenile brown trout that were repeatedly exposed to a 118-percent TDG supersaturation, with 30 days allowed between exposures for recovery, developed more severe symptoms with each new exposure. This study suggests that the assumption that salmonids can fully recover from intermittent or repeated exposures at greater than a 110- to 115-percent TDG supersaturation is questionable and should be avoided during operational conditions where fish travel time becomes slowed.

As previously stated, hydrostatic pressure is increased in water with depth, thus greatly enhancing the capacity of deeper water to hold dissolved gases. Approximately 10 percent more gas can be held in solution at equilibrium for each meter of water depth. As a result, it is a common assumption that fish may sound to some compensation depth to escape or moderate the effects of TDG supersaturation. Empirical data collected during the spill tests conducted during the 1992 *Physical Drawdown Test of Lower Granite and Little Goose Reservoirs* (Wik *et al.*, 1994) indicated that intermediate and maximum supersaturation levels were evenly distributed vertically throughout the water column as the parcel of water traveled downstream. In general, dissolved gas concentrations are evenly distributed vertically. Fish that maintain a position below the compensation depth continue to accumulate a body burden of supersaturated dissolved gas in excess of near-surface equilibrated conditions when the water is supersaturated with TDG. Bubble formation in the vascular system may be suppressed and not expressed until the fish rise nearer the water surface when passing or exiting one of the routes through a dam.

No research has conclusively established whether fish actively or instinctively seek deeper water (if available) to avoid higher levels of dissolved gas supersaturation, or if fish that prefer deeper water habitat survive better than fish that inhabit shallow water. Fidler (1985) found that fish physiologically begin to lose control of the regulation of their swim bladder through the pneumatic duct at gas levels near 111 percent. Alderdice and Jensen (1985) recommended that, in order to prevent the acute mortality of juvenile salmonids and adult sockeye in the Nechako River, total gas pressures should be managed below 110 percent. This recommendation was based upon their observations, wherein a significant amount of the test salmonid population previously exposed to gas levels of 110 to 112 percent of barometric pressure swam to and remained within the shallow water depths containing high TDG supersaturation when deeper water allowing compensation was provided and directly available. The

results of Alderdice and Jensen (1985) tend to support the physiological limitation presented by Fidler (1985) and fit within the bounded estimates between chronic and acute GBT risk (108- to 116-percent TDG) modeled by Jensen *et al.* (1986).

## SECTION 3.0 - POTENTIAL SOLUTIONS TO TOTAL DISSOLVED GAS (TDG) SUPERSATURATION AT ICE HARBOR DAM

### 3.01. GENERAL.

Potential alternatives for controlling or reducing TDG production at Ice Harbor Dam are described and evaluated in the following paragraphs.

### 3.02. ELIMINATION OR REDUCTION OF SPILL.

#### a. Eliminate or Reduce Spilling for Juvenile Fish Passage.

There are two options under this alternative. The first would be to completely eliminate spilling for juvenile fish passage purposes. This would stop the high TDG levels associated with these spills. However, this option would not fulfill the goals of the regional fishery interests for fish passage efficiency (FPE) and would not reduce the high TDG levels that occur when river discharges exceed powerhouse capacity.

The second option is to install extended-length screens in the turbine intakes to improve the fish guidance into the bypass system. This could at least reduce and possibly eliminate spill for juvenile fish passage and still achieve requested FPE goals. However, again like the first option, this would not help to reduce high TDG levels that occur when river discharges exceed powerhouse capacity.

This alternative is not considered a feasible alternative due to the above factors.

#### b. Reduced Spill with High Fish Passage (Surface Spill).

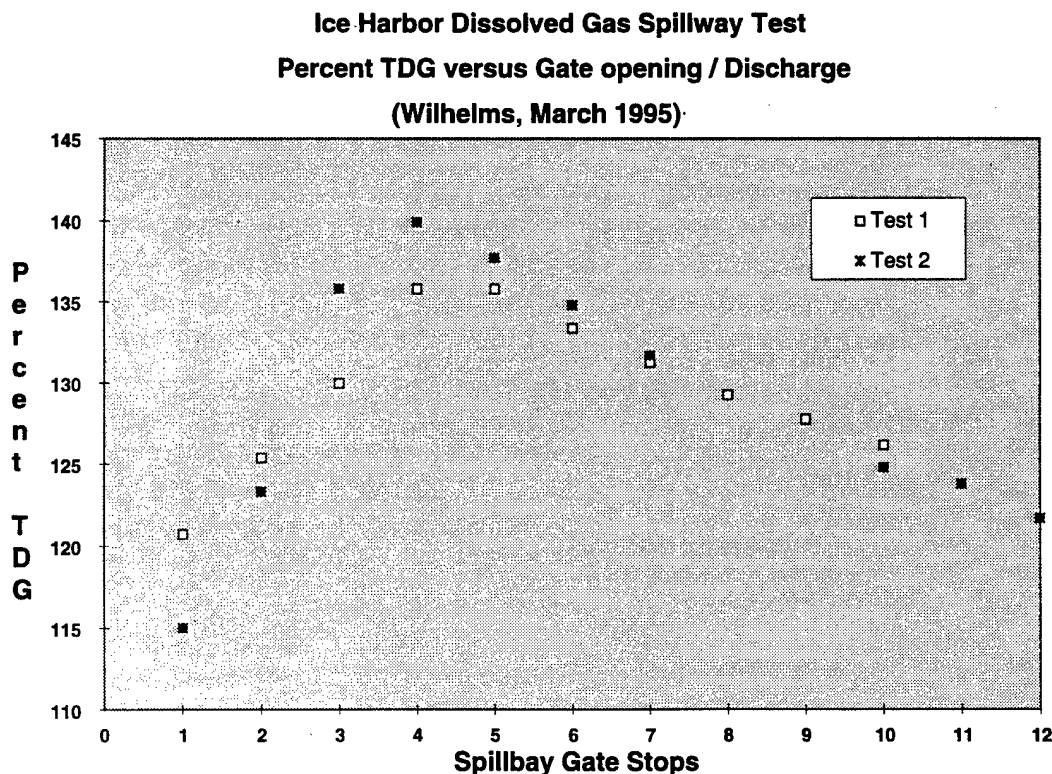
Raymond and Sims (1980) tested diel movement patterns associated with surface spill and turbines. They concluded that surface spilling at John Day Dam could have high potential as a downstream salmon passage route. Their computed survival ranged from 96.5 to 119 percent, with a 95-percent confidence interval for mortality (not significantly different from zero). Preliminary surface collection studies conducted hydroacoustically at Ice Harbor Dam during 1995 also support the implications of the John Day Dam study indicating that percent passage attributable to surface spill treatments was substantially increased over deep spill comparisons. Structural modifications would be required to convert the tainter gate regulated spill released at +40 feet of depth to a new surface spill gate configuration (e.g., roller gate). The Raymond and Sims (1980) study supports the gas abatement concept that reducing spill volume while providing for a high fish passage rate (also known as Well's Dam without the need for an entire hydrocombine-type redesign) would equate to less TDG

production potential. The primary objective of increased nonturbine passage and improved smolt survival would be satisfied.

### 3.03. OPERATIONAL CHANGES.

#### a. General.

In March 1995, personnel from the Waterways Experiment Station conducted a field investigation of four spillways on the lower Columbia and Snake Rivers. The objective of the field study was to collect TDG data to describe the gas transfer characteristics of each spillway. This was accomplished by measuring dissolved gas levels upstream and downstream of each dam over a range of discharges through a single spill bay. A plot of TDG versus spill discharge [in terms of gate stops with approximately 1,700 cubic feet per second (cfs) per spill bay per gate stop] for the Ice Harbor Dam's single spill bay spill test is shown in figure 3.1. Results show that TDG saturation levels remain below 125 percent for spill discharges up to about 2,200 cfs per spill bay. Levels peak at about 140 percent with a discharge of 7,000 cfs per spill bay (4 gate stops) and then drop below 125 percent for discharges greater than approximately 17 thousand cubic feet per second (kcfs) per spill bay (10 gate stops). In an effort to reduce TDG levels when spilling, an alternate spill pattern was developed. This pattern eliminates the use of gate stops 3 through 7 that produced the highest dissolved gas levels.



(Figure 3-1)

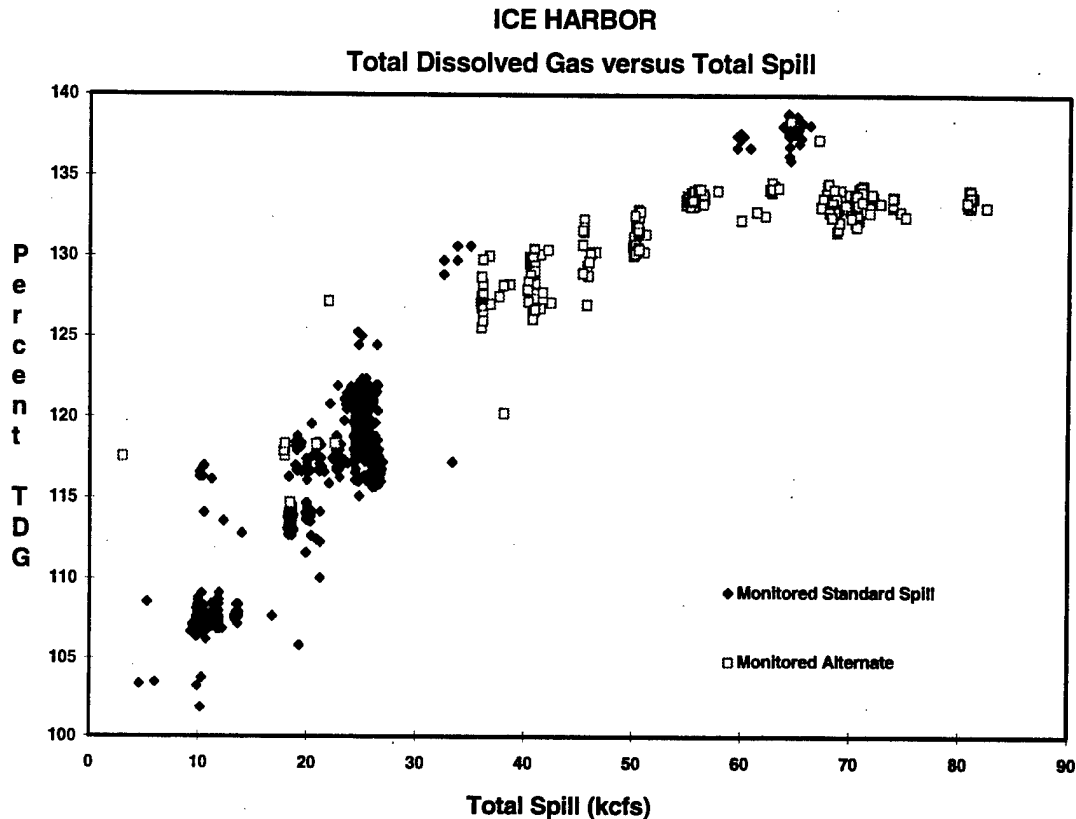
b. Spill Pattern Evaluation.

Two tests were conducted during the 1995 spill season to evaluate the alternate spill pattern. One test was conducted on 25 May with a total spill discharge of 45.5 kcfs and another on 6 June with a total spill discharge of 73.8 and 64.5 kcfs. The TDG gas levels were monitored by boat along transects below the spillway for both the standard spill pattern (table 1) and the alternate pattern (table 2). The results of these tests are summarized below.

	Test 1 (25 May 1995)		Test 2 (6 June 1995)	
Pattern	Standard	Alternate	Standard	Alternate
Total Flow	113 (kcfs)	113 (kcfs)	135 (kcfs)	143 (kcfs)
Spill Discharge	45.5 (kcfs)	45.5 (kcfs)	64.5 (kcfs)	73.8 (kcfs)
Percent TDG Forebay	117	116	111	112
Percent TDG Spill	136	129	136	131

The TDG levels given for spill discharge are an average of data collected along a transect adjacent to the fixed monitoring station downstream of the spillway. Due to an increase in total river discharge during the 6 June test, it was not possible to evaluate the alternate and standard patterns at the same spill discharge. The alternate spill pattern was implemented following the 25 May test. The TDG data recorded by the downstream fixed monitoring station for the 1995 spill season is shown for both the standard and alternated spill patterns in the figure 3-2. The alternate pattern does not deviate from the standard pattern until total spill discharge exceeds 32 kcfs.

Although a slight reduction in the TDG was noticed, saturated gas levels still exceeded 120 percent with spill greater than 25 kcfs. The TDG levels may be reduced by as much as 7 percentage points during high spill discharges of 60 to 70 kcfs. However, before implementing the alternate spill pattern for daytime operations, the hydraulic conditions in the tailrace must be evaluated for impacts on adult fish passage. It is possible to operate the alternate pattern during night spill when the adult fish cease to move into the fishways.



(Figure 3-2)

### 3.04. MODIFIED STILLING BASIN.

#### a. General.

A stilling basin serves to dissipate the kinetic energy of water spilling over a spillway. The dissipation of energy is necessary to prevent excessive erosion and undesirable hydraulic conditions in the tailrace. To dissipate the water's kinetic energy, the stilling basins are designed to create and contain the formation of a hydraulic jump. For the classical hydraulic jump to form, the stilling basin must be designed within certain proportions with respect to the entering flow depth ( $d_1$ ) and the basin depth ( $d_2$ ).

The Ice Harbor Dam spillway is designed to dissipate energy of all spillway discharges up to the spillway design flood (SDF) of 850 kcfs. Hydraulic analysis of the Ice Harbor Dam spillway shows that the design  $d_2$  depth for the SDF is 70 feet. Although the basin invert elevation has been established to form the hydraulic jump at the SDF, the basin normally functions at significantly lower discharges. The available  $d_2$  depth (tailwater elevation minus invert elevation) at Ice Harbor Dam ranges between 36 and 52 feet for total river discharges up to 300 kcfs. Ice Harbor Dam has a much higher concentration of dissolved gas than The Dalles Dam because of its greater available  $d_2$  depth. The greater  $d_2$  depth is required to dissipate a much higher unit energy for the SDF at Ice Harbor Dam than is required for The Dalles Dam. To reduce

the concentration of dissolved gas in the flow released from a stilling basin, an obvious solution is to raise the invert elevation of the stilling basin.

b. Options.

Two alternatives have been considered for a raised stilling basin floor. The first alternative is a raised basin that extends approximately 220-feet downstream from the toe of the spillway to match the tailrace at elevation 322. The second alternative is a stepped basin with the primary basin at elevation 322 and the secondary basin at elevation 304. Both alternatives allow the hydraulic jump to form on a shallow basin floor for flows up to the 5-year event.

(1) Alternative 1 - Raised Stilling Basin, Raised Basin Floor.

Raising the stilling basin floor to match the existing tailrace at elevation 322 would reduce the dissolve gas concentration of spill by reducing the excess available  $d_2$  depth of flows within the normal operating range. Such a basin would have TDG transfer characteristics similar to The Dalles Dam. Preliminary analyses show a basin elevation of 322 provides a  $d_2$  depth sufficient to create the hydraulic jump on the basin floor for spillway discharges up to 120 kcfs with a powerhouse of 88,750 cfs. These flows represent a 5-year event at Ice Harbor Dam and provide a tailwater elevation of approximately 353. The shallow stilling basin would perform very much like The Dalles Dam. Based on the spillway performance test of The Dalles Dam, the TDG levels are expected to reach 118 percent at discharges of 5,000 cfs per spill bay and would then decrease to approximately 112 percent with increased discharges to 11 kcfs per spill bay. However, this solution would allow large spillway discharges (including the standard project flood) to sweep through the basin. The high kinetic energy would dissipate elsewhere downstream in an uncontrolled manner. Such dissipation could result in scour and redeposition of alluvial bank and bed gravels as well as bedrock material in the tailrace, navigation channel, and the surrounding area. Preliminary cost estimates were developed to show the general magnitude of the construction cost. The cost analysis for the raised basin was completed for the *Dissolved Gas Abatement Study, Phase I*, Technical Report, April 1996. The construction cost for the raised basin was estimated at about \$28 million.

(2) Alternative 2 - Raised Stilling Basin, Negative Step Stilling Basin.

A solution for a raised stilling basin floor that would avoid an unacceptable sweep-out would be to construct a deeper stilling basin immediately downstream from a raised stilling basin floor. This type of structure is termed a negative step or abrupt drop stilling basin. It consists of two sections, a primary basin and a secondary basin. A primary basin is the upstream portion with a basin floor at the higher elevation. The secondary basin is the downstream portion with a lower elevation basin floor.

A negative step basin has been analyzed for the John Day and Ice Harbor Dams by Summit Technology, Inc. The analyses and report prepared by Summit Technology, Inc. for the U.S. Army Corps of Engineers, Portland and Walla Walla Districts is included in the *Dissolved Gas Abatement Study, Phase I*, Technical Report, April 1996. The negative step stilling basin analyzed for Ice Harbor Dam will allow frequently-occurring discharges to form a hydraulic jump entirely on the primary basin. It will also allow the larger discharges to form a hydraulic jump either entirely on the secondary basin or, partially on the primary basin and on the secondary basin. Preliminary analysis and calculations performed by Summit Technology, Inc., indicate that the negative step basin would have a primary basin elevation of 322 and a secondary basin elevation of 304. This configuration will permit the hydraulic jump to form on the primary apron for all flows up to 15 kcfs per spill bay (120 kcfs for 8 of 10 spill bays) and a powerhouse flow of 88,750 cfs for a total river discharge of 208,750 cfs. These flows represent a 5-year event at Ice Harbor Dam.

The lengths of the primary basin and the secondary basin are each 180 feet. The secondary basin would be excavated into the channel bedrock to invert elevation 304 and would not be concrete lined, and both sides of the basin would require concrete training walls.

Summit Technology, Inc., used a computer program, developed by Northwest Hydraulic Consultants, Inc., to predict the TDG level of the spill discharge released through the negative step basin. This program was based on a U.S. Bureau of Reclamation concept (P.L. Johnson, *Predictions of Dissolved Gas at Hydraulic Structures*, USBR, 1975). The dissolved nitrogen percentages were predicted for flows that would form a hydraulic jump on the primary basin. These predictions were for total river discharges of 110 to 230 kcfs at Ice Harbor Dam and show that the raised basin may reduce the dissolved nitrogen by about 20 percent. However, based on prototype spillway tests of lower Snake and Columbia River projects, there is some indication that the negative step basin may have performance characteristics between that of The Dalles Dam, which has a shallow stilling basin and tailrace, and those spillways that have deflectors and a deep tailrace.

The step stilling basin prevents the lower discharges from plunging to the full depth of the existing basin as do the deflectors. Spillway deflector model studies indicate that flows greater than about 5,000 cfs per spill bay have sufficient turbulent energy available for air entrapment in the deep stilling basin. These conditions will likely occur with a step basin and may result in gas levels of 120 percent and above. Construction costs for the negative step stilling basin was estimated by Summit Technology, Inc. to be about \$52 million.

c. Engineering Evaluation.

The major cause for the high concentration of dissolved gas at Ice Harbor Dam is the depth of the stilling basin. Under normal spill conditions the available  $d_2$

depth is greater than the required  $d_2$  depth. The excessive available  $d_2$  depth exposes the entrained air bubbles to high internal hydrostatic pressures. A raised stilling basin reduces the depth of entrainment and will limit the production of TDG. Raising the basin 18 feet will limit the production of TDG to less than 120 percent and provide conditions sufficient to dissipate the energy of spill discharges up to 120 kcfs. The hydraulic jump of higher discharges will be swept from the basin, allowing the energy to dissipate elsewhere downstream in an uncontrolled manner. Although these hydraulic conditions can be model tested, the effects on stream bed erosion and resulting impacts on the navigation lock, guidewall, and other appurtenant structures are difficult to predict. An extensive study of the hydraulic conditions and risk analysis is needed before such an alternative could be implemented.

A negative step stilling basin is a two-part basin. The hydraulic jump resulting from normal discharges (discharges up to 120 kcfs) forms entirely on a primary basin that is elevated to reduce the depth of air entrainment. A deeper secondary basin stepped down from the primary basin is designed to contain the hydraulic jump of the higher spill discharges including the SDF of 850 kcfs. As spill discharges increase, the effectiveness of the basin with respect to gas production is reduced. Entrained air bubbles can be carried to depth in the secondary basin resulting in higher gas levels. This basin functions similar to the spill deflectors, in that the low flows are deflected and prevented from plunging to the full depth of the basin; and the high flows are allowed to override the deflectors and utilize the full basin depth for energy dissipation.

Since air bubbles cannot be accurately modeled and there are no available step basins to provide prototype results, it is difficult to predict the gas production for the negative step basin alternative. Model studies are needed for further evaluation of the raised basin and negative step basin. Negative step stilling basins are not common and, as such, only limited information has been found to guide the design. Also, no information has been found to indicate that this typed of basin has ever been used to limit supersaturation of dissolved gas.

A sectional model of the spillway should be used to confirm calculated elevations and assess performance of the two basin alternatives with respect to the hydraulic jump formation and aeration characteristics. The sectional model would also provide for an assessment of the potential for bedrock erosion. The Ice Harbor Dam general model should be used to evaluate the effects of high and normal flow conditions on navigation and adult fish passage. This model would also be used to investigate the need for training walls and to evaluate the hydraulic conditions in the tailrace and downstream channel. The general model should also provide insight into rock movement within and downstream of the stilling basins.

### 3.05. DEFLECTORS.

#### a. Description.

Spillway deflectors serve to reduce the plunge depth. The spillway discharge is deflected horizontally and skims across the surface instead of plunging the full depth of the basin. Unfortunately, the spillway deflectors have a very limited effective operating range.

#### b. Evaluation.

It is estimated that installing deflectors on the Ice Harbor Dam spillway would reduce TDG levels by up to 5 to 10 percentage points (e.g., reduce TDG from 120 percent to 110- to 115-percent saturation). Even this small amount of reduction can have significant biological benefits. This estimated reduction is based on an extrapolation of data collected at Lower Monumental Dam (both before and after the addition of deflectors) to Ice Harbor Dam (the spillway design of these two projects is very similar). Sectional model tests indicate that this maximum reduction of TDG is likely to occur for spill discharges up to 60 kcfs.

### 3.06. SUMMARY.

Reducing or eliminating spills for juvenile fish passage is not a feasible alternative currently and would not provide any reduction in TDG levels during times of high river discharges requiring the use of the spillway to pass excess flows. Making changes to the operation of the spillway have proven to be an ineffective way to make significant reductions in TDG levels. Also, there is insufficient information available, at this time, to recommend modifying the stilling basin. However, spillway deflectors do provide significant reductions in TDG levels; though they have limited ranges of effectiveness and do not completely eliminate concerns about high TDG levels resulting from the use of the spillway.

## SECTION 4.0 - BIOLOGICAL EVALUATIONS OF DEFLECTORS

### 4.01. REVIEW OF JUVENILE FISH SURVIVAL OVER SPILLWAYS.

The Ice Harbor Spillway Deflectors Letter Report (October 1994; preliminary) reviewed historical survival tests conducted with juvenile fish passing over spillways (see section 5.02.a.). In general, direct mortality has been estimated to be no greater than 3 percent [March 2, 1995, National Marine Fisheries Service Biological Opinion, *Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years* (Bi-Op)]. Indirect mortality associated with spill and the potential negative effects of spill that may occur due to gas supersaturation are not well known.

The Ice Harbor Spillway Deflectors Letter Report also referenced tests conducted with juvenile fish with deflector and non-deflector bays (see section 5.02.b.). In summary, two data sets (Johnson and Dawley, 1974; and Muir *et al.*, 1995, as supported by Iwamoto *et al.*, 1994) suggest no statistically significant difference in survival between deflector and non-deflector spill bays, although measurable differences of 4- to 5-percent less survival with deflectors were found. A third data set (Long *et al.*, 1975) suggests higher mortality with a non-deflector spill bay. If the Long *et al.* data is in fact an anomaly [National Marine Fisheries Service (NMFS), personal communication], installation of deflectors may actually decrease the survival of juvenile migrants by up to 5 percent. It is important to note that neither of these studies resulted in survival differences that were statistically significant, but the trend in measurable negative differences raises a concern as to probability in the successful ability to derive net biological benefit of deflector installation. This caution is due to the trade-offs between the need to incrementally reduce percent total dissolved gas (TDG) for some interim timeframe and the ability to reestablish optimal localized hydraulic conditions conclusive to a no-net loss in smolt survival.

Any potential spillway modification needs to be evaluated with regard to direct and indirect effects on salmonid mortality. Direct mortality includes immediate death specifically associated with passage through the spillway and stilling basin, whereas indirect mortality relates to factors causing death through related secondary vectors such as increased susceptibility to perdition. Bell (1972), Bell and DeLacy (1972), and Ruggles and Murray (1983) comprehensively reviewed existing data on the survival of fish passing through spillways. They describe seven mechanisms independent of dissolved gas effects in which fish may be injured upon passage through spillways:

- a. Rapid pressure change.
- b. Rapid deceleration.
- c. Shearing effects.

- d. Degree of turbulence.
- e. Striking force of fish on the water surface.
- f. Scraping and abrasion.
- g. Length of time juveniles spend in highly turbulent water.

More basic research is needed on existing structure designs and materials because little information is available that describes the relative importance of each of these factors on fish survival. Bell and DeLacy (1972), and Ruggles and Murray (1983) reviewed the factors on fish response to impacts on structures, abrasion on rough concrete faces, various forces associated with deceleration, and the types of injuries sustained. Some studies such as Groves (1972) discussed the effects of shearing forces, which are differences in velocity flow planes causing excessive acceleration and deceleration. Groves (1972) revealed damage to fingerlings coming into contact with water moving in excess of 30 feet per second. Their hypothesis suggests that fish can be injured in a high energy flow where momentary localized points of sharp velocity differences occur. Under best passage conditions (hydraulics associated with the jet), Bell and DeLacy (1972) hypothesized a 93- to 98-percent survival range under best hydraulic conditions through a hydraulic jump or large and deep stilling basin without mechanical deflection (such as encounter with a baffle) could equal survival under best free fall conditions. Tailrace hydraulics associated with the jet reentering the spillway basin and associated shears apparently determine the level of survival within this range. They suggest that survival rates could approach zero for fish striking a fixed baffle or object in the jet pathway exiting the spillway. This physical process is the engineering objective of baffle placement for enhancing water energy dissipation. Ruggles and Murray's (1983) conclusions are consistent with those of Bell and DeLacy (1972) and Bell (1972), suggesting that turbulence in the energy dissipating area should be minimized by lengthening the crest of the spillway, deepening the stilling basin, increasing the cross sectional area of the spill, or dissipating the energy in several stages.

Flow deflectors have been designed to change localized hydraulic conditions and affect survival based upon tri-depth velocity magnitude and direction estimates derived from physical model testing. At some flows and gate patterns, non-deflector spill bay operation for adult salmon ladder entrance attraction can create submerged lateral flow directly below adjacent deflector's vertical face, while surface flow can be directed back toward the spill bay to be recirculated. The 1994 Lower Monumental data set may be showing the range in survival associated with best jet conditions for passage at a spillway spill bay [e.g., 98-percent survival with the non-deflector spill bay (representative of better localized hydraulic conditions) versus 93 percent with a deflector (representative of affected localized hydraulic conditions)]. This relationship appears to be supported by Bell's (1972) and Bell and DeLacy's (1972) review. While

it is not known if similar hydraulic mechanisms are involved at Ice Harbor Dam, it is likely that similar effects would be associated with the installation of deflectors.

#### 4.02. CURRENT AND PROBABLE FUTURE SYSTEM-WIDE OPERATIONS.

System operation has critical weight on the biological benefits attributable to the addition of spillway deflectors at a single dam. If the hydrosystem is operating under an extended high spill schedule (greater than 3 days voluntary or involuntary spill), deflectors at a single dam would have no biological effectiveness rating for improving smolt survival at the system-wide scale. If the hydrosystem is operated under a full powerhouse schedule, the elevated TDG supersaturation resulting from 2 to 3 days of peak runoff flows, forcing involuntary spill, could be moderately reduced with some biological benefit. Also, low power demand or turbine maintenance periods at a single dam could force a spill operation that could be moderately compensated by spillway deflector installation. This would also apply to the single dam effect of a spill operation for fish passage similar to the 1993 voluntary spill operation at Ice Harbor Dam.

The installation of deflectors at Ice Harbor Dam (the single remaining Snake River dam without these structures) would have a variable effect in magnitude in fish survival due to TDG production. Any potential biological and ecological benefits would be evaluated in cumulative fashion, as related to the single dam's effective contribution to the entire system's biological effectiveness. In this operational scenario, a much greater percentage of the outmigrating population would be affected for a longer period of time (*i.e.*, greater than 50 percent of the spring chinook population during an average year. NOTE: This was not the case during the 1994 spring chinook operation since the emergency operation was not implemented until about 75 percent of the run had passed Lower Granite Dam).

Chronic exposure (as opposed to acute exposure and its level of associated stress) and gas bubble trauma (GBT) symptom formation would occur as the TDG supersaturation and fish exposure time accumulates downriver. These factors become increasingly more important to juvenile salmonid survival and vitality. If the mortality threshold is set at 108- to 114-percent TDG saturation (as suggested by dose-response research compiled and regressed by the University of Washington) and the TDG supersaturation in the river is greater than 120-percent saturation, continued exposure of longer than 45 days would negatively effect nearly all of the original 50 percent of the outmigrating population.

If spillway deflector installation at Ice Harbor Dam could reduce the TDG supersaturation in the river from 120 percent to between 110 and 115 percent, the negative effect from TDG supersaturation could be reduced to about 40 percent of the original 50 percent of the outmigrating population for that single dam location only. In addition, nearly 100 percent of the original 50 percent of the outmigrating population could be affected at the other 7 dams within the lower Snake and Columbia River corridors. These same fish may be exposed to elevated TDG supersaturation passing

through three dams and reservoirs prior to arriving at Ice Harbor Dam and may be exposed to elevated TDG supersaturation at four additional downriver dams. Therefore, to protect sensitive salmonid juveniles, the concentrations of TDG supersaturation allowed system-wide and regulated by spill quantity is the true measurable determinant of impact on the total fish population, not the percentage of flow spilled to achieve the target fish passage efficiency (FPE) of the 1995 Bi-Op.

Spill at Ice Harbor Dam in 1993, 1994, and 1995 was constrained to 25 thousand cubic feet per second (kcfs) so as not to exceed a 120-percent TDG saturation threshold. The addition of spillway deflectors at Ice Harbor Dam could allow an estimated 45 kcfs to be spilled, instead of the 25 kcfs. The same 120-percent TDG saturation target could be achieved with the 45 kcfs spill cap that was achieved with the 25-kcfs spill cap. The ability to increase the percent spill up to 45 kcfs would allow the 80-percent FPE target in the 1995 Bi-Op to be achieved at a higher frequency under a higher total river flow.

In 1993, submerged traveling screens were installed in the turbine intakes at Ice Harbor Dam. The fish guidance efficiency have been estimated between 55 to 78 percent for spring chinook salmon [point estimate by NMFS is 55 percent weighted by passive integrate transponder-tag analysis) and 93 percent for steelhead (Brege *et al.*, 1988). Voluntary spill for juvenile fish passage was limited to 25 kcfs to maintain dissolved gas levels below 120-percent TDG under the current condition without deflectors. It does remain likely that spill volumes of 25 kcfs will again be required at Ice Harbor Dam in 1996 to achieve Bi-Op requested conditions between 15 April and 31 August.

Currently, the powerhouse turbines are operated during the juvenile fish migration season within 1 percent of peak efficiency translating to a maximum powerhouse flow capacity of about 88 kcfs, which is equivalent to about 4.5 turbines at maximum capacity instead of 6 turbines. Adding the 25-kcfs spill cap for not exceeding 120-percent TDG equates to 113-kcfs river flow, or 22-percent spill. The NMFS identifies that 27-percent spill would be required for achieving the 80-percent FPE target for yearling chinook salmon and 70 percent for subyearling chinook salmon. If 45 kcfs could be spilled and not exceed 120-percent TDG, then 40 percent of the total river flow at 113 kcfs would be spilled, and the 80-percent FPE target would be satisfied up to 133 kcfs total river flow with maximum powerhouse operation for yearling chinook salmon. Powerhouse capacity does not influence the ability to achieve the 80-percent FPE target with subyearling chinook to the degree it does with yearling chinook. The 80-percent FPE target could be achieved with 45-kcfs spill up to 65-kcfs total river flow without an appropriate adjustment for increasing water temperature during the summer.

It is possible that 1 or 2 turbine units may be inoperable through May 1996, requiring spill over the newly estimated 45-kcfs design range of the deflectors. Similar to 1995 outmigration season conditions, up to 60- to 70-kcfs forced spill would occur if

greater than 120 kcfs is produced within the lower Snake River sub-basins by runoff or precipitation. The installation of flow deflectors on Ice Harbor Dam would not be able to reduce the potential TDG production below 120-percent TDG under this scenario, although it is estimated that their operation would reduce the potential maximum TDG production up to 5 to 10 percent.

#### 4.03. JUVENILE FISH EVALUATION.

The duration of exposure related to time-to-death is co-dependent on many variables and cannot be easily determined. However, it can logically be assumed that lower levels of TDG supersaturation would afford better protection for individual fish constituting the migratory population, ultimately resulting in fewer sublethal or lethal barriers to survival. Therefore, a presumed 5- to 10-percent reduction in TDG supersaturation applied to deflector operation at Ice Harbor Dam could potentially provide relatively short-term inter-seasonal benefits to juvenile salmonid survival (less than an expected 2-percent increase) as they pass through Ice Harbor Dam and the subsequent downriver reaches. These short-term benefits would be more representative of forced spill and high flow, low energy demand events lasting only a couple of weeks. They become insignificant when averaged across a long-term trend calculated for salmonid protection and recovery (e.g., the 50- to 61-year record of flow). Benefits could be significant within a single-flow year (e.g., total river flows greater than 120 kcfs during the peak outflow in May of a high-flow year), but only for that percentage of the outmigrating population that passed the dam in those 3 to 7 days. The total benefit that could be expected for any one year would depend on the timing within the season and travel time, in relation to the percentage of population that passed during that time, as well as the frequency of the forced spill pattern (e.g., either tail-end of the passage distribution versus peak of migration). This could result in potential benefits between 2- to 5-percent survival applied to about 20 percent of the total passage population for that single season under low frequency events of forced spill and high flow, low energy demand operations.

In theory, any possible biological benefits achieved with a 5-percent reduction in TDG supersaturation should have potential incremental benefits if a 10-percent reduction in TDG supersaturation could be produced. It is assumed that this increase could be scaled proportionally above the 5-percent reduction. An absolute +10-percent reduction in TDG supersaturation should be more influential on fish survival because it could reduce a high, lethal supersaturation level to a sublethal level. For example, a reduction to the Environmental Protection Agency-determined safe level of 110-percent TDG (no or only minor symptoms occur) instead of 115-percent TDG (sublethal level where acute or chronic gill lamellae and vascular bubble formation occurs) from a 120-percent value (the lethal level leading to chronic physiological stress or ultimately mortality). Obviously, if spill occurs system-wide producing TDG supersaturation near 125 percent, any marginal benefit in a presumed 5- to 10-percent reduction of TDG supersaturation at a single dam (e.g., installing spillway deflectors at Ice Harbor Dam) would be insignificant at the system-wide scale because only TDG supersaturation

reduction maintained below 115 to 120 percent (sublethal to physiological functions) could be expected.

To gauge the potential additive effects of "the sum of the parts equaling the whole" relationship, the recently recalibrated Columbia River Salmon Passage (CRiSP) juvenile passage model was exercised. This produced a sensitivity analysis for estimated increased smolt survival related to additive or cumulative effects of 5- to 10-percent TDG reduction for single projects. For system-wide effects, deflector installation at the last remaining singular dam in the lower Snake River without deflectors would provide such insignificant benefits (about 2 to 3 percent) to system-wide salmonid passage survival that net benefits in system survival for smolts would not be measurable with any degree of confidence. A 5- to 10-percent TDG reduction at Ice Harbor Dam alone would not provide adequate benefits at the system survival scale. The sensitivity analysis indicates that a 5- to 10-percent TDG reduction at each of 2 to 4 lower Snake River dams would have to be accomplished, with Little Goose Dam being the next highest priority for structural treatment. Little Goose dam already has flow deflectors, so a much larger-scaled structural modification to each lower Snake River dam, beyond the deflectors' effective design limitations, will be required to produce a greater than marginal biological and ecological benefit to salmonids passing in-river.

In conclusion, the current Bi-Op for 1995-98 Federal Hydrosystem Operation requests for 50 percent of collected smolts to be transported and 50 percent to be bypassed back to the river to continue their downriver migration. This in-river proportion of smolts applied to the assumed 1:1 ratio of percent spill:percent number of smolts passing through the spillway would suggest some increment of biological benefit to the total in-river component of the migrant population if TDG supersaturation could be decreased an absolute 5- to 10-percent TDG at the hydrosystem-wide scale of measurement.

In support of this conclusion, two out of three spillway survival studies directly comparing spill bay passage survival between spill bays with deflectors versus without deflectors, performed at Bonneville and Lower Monumental Dams, suggest that direct mortality slightly increases when fish are passed through a deflector spill bay versus passage through a non-deflector spill bay (Johnsen and Dawley, 1974 and Muir *et al.*, 1995 versus Long *et al.*, 1975). This less than 5-percent potential increase in mortality due to deflector installation at Ice Harbor Dam provides a no-net benefit conclusion in comparison to the 2- to 3-percent increment in system survival that could be attributed to an absolute 5- to 10-percent TDG reduction from flow deflector installation.

#### 4.04. ADULT FISH EVALUATION.

##### a. General.

Data suggests sublethal impacts of TDG supersaturation can begin to occur in adults exposed to TDG below the 110-percent range, with lethal impacts occurring before 115 percent. Depth of travel and fish condition are significant factors. Actual observation of GBT in adult fish within this range is difficult to detect visually, but vascular system bubble formation within gill lamellae is well documented. Exposure duration and time to death can not be determined, but better protection and fewer sublethal or lethal impacts to the pre-spawning success of migrating adult salmonids will occur with lower levels of TDG. Therefore, a 5- to 10-percent reduction in TDG, if achievable with the installation of deflectors, could benefit exposure time for adult salmonids passing through the Ice Harbor tailrace. However, if deflectors effect passage behavior and entry success due to modified localized hydraulic conditions in the tailrace, resulting in longer passage times, the net benefit would be reduced or even nullified.

##### b. Possible Effects of Deflectors on Adult Fish Passage.

Bjornn and Peery (1992) review the research history on migrations past dams and discuss the various factors involved (*i.e.*, entry into fishways, tailrace flow patterns, spillway discharge patterns, and collection channel preferences). The authors review the history of spillway deflectors in the 1970's, along with the resulting adjustments to spill patterns needed to maintain adequate passage conditions. The higher surface velocity associated with deflectors is cited as the reason involved in the Junge and Carnegie (1976) recommendation not to install deflectors at Ice Harbor Dam.

Spill patterns were evaluated by Junge (1967b) in 1966 and 1967 at Ice Harbor Dam to determine the most effective pattern for adult passage conditions. A crowned or V-shaped spill pattern was found preferable to the uniform pattern used from 1963 to 1966. The existing Ice Harbor spill pattern developed by Junge and Carnegie (1972) creates a V-shaped zone of turbulence below the stilling basin. This pattern results in a high velocity migration barrier to adult fish and tapers upstream towards the outside spill bays, adjacent to the fishway entrances. Fish are guided along the northern edge towards the north spillway entrance and an eddy that develops downstream of it. This eddy has been observed during most spill operations and varies in size and intensity depending on discharge levels. With low spill levels, the discharge from the north spillway entrance is sufficient to attract adults into its region of influence. However, as spill discharge begins to exceed 35 kcfs, the influence of the attraction flow begins to diminish. Although the north powerhouse entrance generally performs well under most spill conditions, few adult chinook salmon enter the fishways as spill levels approach and exceed 50 kcfs.

In 1976, a general model of Ice Harbor Dam was used to evaluate the effects of spill bay deflectors on adult fish passage. (Reference: *Ice Harbor General Spillway Model Deflector Study*, Report No. 1, August 23, 1976.) Spillway deflectors were set at elevation 336 to provide optimum performance for involuntary spill. Flow patterns were evaluated without deflectors as the baseline conditions and with deflectors on spill bays 3 to 8, 2 to 9, and 1 to 10. Tailrace conditions were observed and evaluated with river discharges of 160 kcfs (2-year flood), 210 kcfs (5-year flood), 250 kcfs (10-year flood), and 420 kcfs (standard project flood). The best attraction conditions were obtained at the fishway entrances with deflectors installed in spill bays three to eight. However, there was no indication that lower river discharges were evaluated in this model study.

Among the reasons given for not installing spillway deflectors following this study was the remaining dams upstream of Ice Harbor Dam already had spill bay deflectors. In addition, Ice Harbor Dam had expanded from three turbine units to six and the schedule for expanding from three to six turbines on the upstream projects was accelerated.

Radio-tracking studies were conducted by Monan, Liscom, and Stuehrenberg in the early to mid-1970's to determine the effects of spillway deflectors on adult salmonids. A pilot installation of deflectors (two of eight spill bays) was completed at Lower Monumental Dam in 1973 (Monan and Liscom, 1974). Fish behavior in the spill basin was monitored with radio-tracking. Another study of fish behavior, in relation to a partial installation of deflectors, was carried out at Bonneville Dam in 1974 (Monan and Liscom, 1975). In this study, 4 of 18 spillway spill bays were outfitted with deflectors. No negative information was developed in these two studies. Radio-tracking studies were also conducted in 1975 at Bonneville Dam (Monan and Liscom, 1976) and Lower Granite Dam (Liscom and Monan, 1976), where a full complement of deflectors was already installed. The authors did note that hydraulic conditions effected the entry of adult salmonids to fish collection facilities, but assumed spill patterns could be manipulated to enhance passage. No evidence was found that suggested debilitating injuries to those radio-tracked fish that did enter into the more turbulent hydraulic zones immediately below the deflectors.

Passage for adult spring chinook at Ice Harbor Dam was compared to passage at the other Snake River projects in 1993 when spill conditions were in effect during the May to early June timeframe. The Idaho Cooperative Fish and Wildlife Research Unit (ICFWRU) was conducting radio telemetry studies [using Digital Spectrum Process equipment] at the four Snake River projects (the third year of a proposed 4-year study of spring chinook and steelhead). The first 2 years of field study (1991 and 1992) were conducted under periods of no spill. The 1993 water year provided spill for passage evaluation. The adult portion of the tracking program for 1994 was canceled due to low adult returns. Therefore, data for the 1994 spill program is not available.

Several comparisons were made in an evaluation of the adult fish passage conditions at Ice Harbor Dam with no deflectors, relative to passage conditions at the other Snake River projects with deflectors. First, passage time at Ice Harbor Dam with and without spill, versus passage at the other dams, was reviewed [table 4-1 is data analysis by the ICFWRU (Bjornn *et al.*, 1994)].

Table 4-1 - Median Time to Pass Snake River Projects in 1993 Based on Seasonal Passage Estimate	
Project <sup>1/</sup>	Median Time (days)
Ice Harbor (all season)	0.78
Lower Monumental (8 weeks of spill)	0.85
Little Goose (8 weeks of spill)	0.70
Lower Granite (2 weeks of spill)	0.76

<sup>1/</sup> Duration of spill noted in parenthesis.

Overall passage times appear similar with or without deflectors. Ice Harbor, Lower Monumental, and Little Goose Dams experienced spill conditions for the majority of the spring period with no differences in passage time noted. Most of the fish passing Lower Granite Dam did so under no-spill conditions with comparable passage times. Each dam is different (hydraulics, entries, spill basin configurations, *etc.*) but, on a gross comparison basis, spill with or without deflectors did not seem to affect overall passage rates.

At Ice Harbor Dam, data is available only for the condition without deflectors. The following questions must be addressed: 1) Would the amount of deflectors at Ice Harbor Dam significantly increase or decrease passage times for adult salmon and steelhead?, and 2) If an increase in passage time did occur with the installation of deflectors, would it be offset by reduced TDG concentration and lower exposure levels, but longer exposure times?

To evaluate these questions, time-to-first approach and first entry by spring chinook salmon were evaluated. For the basis of this comparison, it was assumed that first approach to an entrance would be the most reasonable criterion to use, as it indicates the ability of the fish to find an entrance. First entry was also compared, as one measure of success in actually entering into the collection channel. Conditions

affecting the location of, and entry into, the collection channel (i.e., the presence/absence of deflectors, particularly adjacent to end spillway spill bays, spill levels, and spill patterns) may show the influence of their operation on adult fish approach/entry. It was assumed that, if no difference was detected between Ice Harbor Dam (with no deflectors), Lower Monumental and Little Goose Dams (no deflectors on the two end spill bays), or Lower Granite Dam (all spill bays have deflectors), the influence of deflectors (at least on approach/first entry) may not be a significant factor.

There appears to be no difference in passage times on first approach or first entry, based on a seasonal estimate for spring chinook salmon at Ice Harbor Dam relative to the Snake River projects with deflectors. Under spill conditions, Lower Monumental Dam has a longer time for approach or entry than the other projects (Lower Monumental Dam, like Little Goose Dam, has deflectors except for the end spill bays). Under no spill conditions, there appears to be no difference in passage times, with first approach or entry, among the Snake River dams. The effect of spill volume (low, medium, high) on time to first approach or first entry does not appear to effect passage up to 50 kcfs.

A 1:55 scale Ice Harbor Dam model was also used to evaluate spillway deflectors and potential impacts on adult fish passage. Tailrace conditions were evaluated and observed for total river flows of 50 kcfs (minimum summer flows) to 150 kcfs (upper limit for adult movement in the Snake River system). Observations included baseline conditions as well as spillway spill bays 6, 8, and 10 deflector performance with and without extended-training walls. A summary of general observations and criteria used to evaluate the potential impacts on adult passage is included in section 5.06. (Deflector Influence on Adult Fish Passage Conditions).

c. Possible Effects of Deflectors on Adult Fish Fallback Survival.

Little is known about survival of adult salmonids passing over spillways. Nothing is known about any differential survival rates of adults passed over deflector-equipped spill bays versus non-deflector equipped spill bays. Intuitively, however, it seems possible that, because of their greater mass (and force), adult salmonids may be more likely to come into contact with the deflectors than would smolts. Whether this contact would cause greater injury than contact with the tailwater is unknown.

d. Conclusion and Recommendation for Adult Fish Passage.

Based on current Ice Harbor Dam passage rates (first approach, entry, and total passage) relative to Snake River projects with deflectors, as well as the results of the 1996 1:55 scale model studies, it appears tailwater conditions with 8 spillway deflectors at Ice Harbor Dam should provide adequate adult fish passage for spill discharges as high as 45 to 60 kcfs. Although flow conditions did not appear to be significantly worse than the existing conditions for this spill range, they can be greatly

improved over the existing conditions by extending the training walls between spillway spill bays 1 and 2, and 9 and 10.

A post-construction evaluation using radio telemetry (potentially piggy-backed onto the Lower Columbia River Adult Passage Study, initiating in 1996) will be programmed into the Anadromous Fish Evaluation Program. Any negative impacts to juvenile and adult fish passage would have to be evaluated relative to improvements in TDG levels, and a plan of action developed to address any negative impacts.

Since adult attraction during spill operations for smolts is one of the most critical criteria for acceptance of deflector installation at Ice Harbor Dam, the general model (1:55 scale) at Waterways Experiment Station (WES) continues to be exercised to develop an acceptable adult passage pattern where the localized hydraulic conditions are at least as efficient to adult salmon ladder entrance attraction and passage as the current crowning pattern under non-deflector conditions.

Basing the physical model evaluation upon the criteria that hydraulic conditions in the tailrace under deflector operation will not be any worse than the current hydraulic conditions under non-deflector operations across a spill flow range up to 45 to 60 kcfs, an acceptable pattern was coordinated by the U.S. Army Corps of Engineers (Corps), NMFS, and University of Idaho biologists and hydraulic engineers. A minimum of eight deflectors was found acceptable by NMFS representatives and should provide interim hydraulic conditions for adult ladder attraction for one passage season. Additional modeling and design review would evaluate whether the two outside spill bays (spill bays 1 and 10 resulting in a full complement of 10 deflectors) and training wall(s) would be installed in a subsequent construction effort. This would be summarized and reported in a letter supplement to this design memorandum and would include regional coordination through the Fish Facility Design Review Work Group process.

#### 4.05. BIOLOGICAL CONCLUSIONS AND RECOMMENDATIONS.

##### a. Potential Benefits and Detriments of Deflectors.

The continued declining trend of listed lower Snake River salmon stocks requires that immediate actions to benefit smolt and adult survival through the hydrosystem be evaluated and implemented. This priority, along with the regional assumptions and desires for in-river passage, requires the Corps to readily develop TDG abating designs for which the agency has previous experience. At the time of the NMFS 1995 Bi-Op, the design for flow deflectors was forwarded as the most timely alternative for incremental reduction in TDG supersaturation system-wide. An analysis using Lower Monumental Dam TDG data collected prior and post to deflector installation was used to estimate a reasonable range of TDG reduction potential of 5 to 10 percent. This reduction could provide a relative estimate of 2- to 3-percent increase

in smolt survival as modeled in the recent calibration of the CRiSP juvenile passage model. This 2- to 3-percent increase in survival could be overridden by up to a 5-percent increase in mortality resulting from direct mechanisms. (NOTE: This increase in mortality was a measurable but not statistically significant difference.) This tradeoff between low mortality increases and decreases would result in a no net biological benefit.

Installation of up to 10 deflectors at Ice Harbor Dam might allow the increase in spill from the current 25 kcfs cap to a 45 kcfs cap while maintaining the same 120-percent TDG measured in the tailrace. This increase in the spill cap could incrementally increase the frequency of achieving the 80-percent FPE target in the NMFS 1995 Bi-Op.

Though flow deflectors provide a small but definite benefit, their installation may prevent or complicate testing of new, larger scale measures that have the potential for greater TDG improvement. The following charts presents the potential benefits and detriments of proceeding immediately with deflector construction at Ice Harbor Dam.

#### Potential Benefits

1.	Estimated 5- to 10-percent reduction in TDG.
2.	Adult passage conditions appear acceptable for all spill discharges up to 60 kcfs (based on observations of hydraulic model tests at WES).
3.	The 120-percent TDG spill cap is expected to increase from 25 kcfs to 45 kcfs allowing higher frequency of 80-percent FPE achievement.
4.	TDG reduction for spills up to 60 kcfs with marginal reductions in TDG for spills greater than 60 kcfs.
5.	Least cost alternative for immediate interim benefit.

### Potential Detriments

1. If a better, long-term reduction of TDG is achievable through the dissolved gas abatement study, there will be only a relatively small, interim benefit for the substantial expense and effort of constructing deflectors.
2. Spillway deflectors have a limited ability to reduce TDG levels. Water quality criteria of 110-percent TDG will not be met for total spills greater than 25 kcfs.
3. Spillway deflectors have a limited range of spill over which optimum reduction of TDG occurs. For spills greater than 60 kcfs, the effectiveness of deflectors diminishes as spill levels are increased. Spills greater than 60 kcfs result from river discharges that exceed powerhouse capacity (due to high river discharges alone or high river discharges with turbine unit outages).
4. Risk that deflector design causes an increase in mechanically caused juvenile fish mortality that negates the benefits of reducing TDG by 5 to 10 percent. (To reduce this risk, the deflector design includes:  
1) a 15-foot-radius fillet between the spillway and deflector and  
2) deflector pier blocks just downstream of the piers.)
5. Although tailrace conditions appear acceptable for adult passage for all spills up to 60 kcfs, there may be increased delays of adult fish to the North Spillway Entrance as spill exceeds 45 kcfs. (However, extending the north training wall in conjunction with deflectors will likely provide conditions which are better than existing conditions. Additional model testing will be conducted and reported in a letter supplement to this design memorandum.)
6. Precludes testing under baseline conditions of potentially more biologically beneficial prototypes and concepts, such as raised stilling basin and/or tailrace or reduced flow through surface spill, independent of deflector effect once installed.
7. Allowance of higher spills for juvenile fish passage could increase adult fallback rates.
8. High risk to fish condition during construction phase if runoff flows force overgeneration spill forcing contractor out (limited to construction period).

### Potential Detriments Continued

9.	Unknown risk to fish condition and adult delay related to construction activity during 2 full seasons to complete final configuration, up to 10 deflectors and extended training walls.
10.	Potential decrement of per spill bay TDG stabilization with deflectors versus potential reduction in TDG over a larger spill range with raised stilling basin (based on The Dalles Dam spill to TDG relationship).

#### b. Summary.

Low, current and projected future fish estimates for Snake River listed stocks emphasize the need to proceed rapidly with any measures that can immediately improve fish passage conditions on the Snake River. Anticipated operations on the Snake River will likely include some level of spill to reach FPE goals at Corps projects. The TDG problem could seriously limit the ability to reach these goals. During spill operations, Ice Harbor produces the highest TDG levels in the system.

Spillway deflectors will provide an estimated 5- to 10-percent improvement in TDG levels for fish spill and will improve the likelihood of meeting FPE goals. Model studies have indicated that deflector installation should not adversely affect existing adult fish passage rates at Ice Harbor Dam. In addition, improvements to the deflector design, such as the 15-foot-radius transition and deflector pier blocks, should reduce the risk that deflectors will increase mechanical injury or mortality to juvenile fish during spill. This may reduce concerns raised in juvenile fish data sets suggesting a measurable (but not statistically significant) mortality associated with deflector passage.

Considerable uncertainty exists with other larger-scale TDG improvement measures. Significant time and effort will be necessary to determine if these measures do provide a significant level of improvement without causing other adverse conditions.

Based on the above discussion, installing eight deflectors is biologically acceptable until a better, more comprehensive solution to TDG is feasible and implementable. Additional model testing should be conducted to explore potential improvements from constructing training wall extensions and deflectors in the end spill bays.

## SECTION 5.0 - DEFLECTOR DESIGN

### 5.01. GENERAL.

The objective of spillway deflectors is to deflect flows along the tailwater surface so that the air entrained within the flow is not carried down deep in the stilling basin. The effectiveness of deflectors in achieving this objective is dependent on the quantity of flow being spilled, the size and shape of the deflector, and the submergence of the deflector (tailwater elevation minus the elevation of the deflector).

### 5.02. SPILL DISCHARGE CRITERIA FOR OPTIMIZING DEFLECTOR DESIGN.

Spillway deflectors will likely reduce total dissolved gas (TDG) supersaturation by 5- to 10-percentage points (see appendix C). If a reduction of 10-percentage points is assumed, then TDG levels are likely to be 110 percent for a spillway discharge of 25 thousand cubic feet per second (kcfs) and 120 percent with a 45-kcfs spillway discharge. State water quality standards and Federal water quality guidelines limit TDG supersaturation levels to 110 percent. Recently, however, the limits were relaxed temporarily to 120 percent in order to increase the number of juvenile fish passing the project via the spillway. If spills are continued in the future to maximize juvenile fish passage via the spillway, the most prevalent spill discharge level after deflectors are constructed would most likely be between 25 and 45 kcfs, depending on the effectiveness of the deflectors and what level of TDG supersaturation is tolerated. The performance of the deflectors for this range of discharges in the model tests was examined carefully when trying to optimize the design of the deflectors.

### 5.03. TAILWATER ELEVATION CRITERIA.

The tailwater elevation below Ice Harbor Dam is largely dependent on the discharge of the Snake River. A target for minimum river discharges for the lower Snake River during the spring outmigration season is given in the March 2, 1995, National Marine Fisheries Biological Opinion, *Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years* (Bi-Op). The target is 85 to 100 kcfs, depending on the April-July runoff volume forecast. The target during the summer season is 50 to 55 kcfs and is also based on the runoff volume forecast.

The tailwater elevation at Ice Harbor Dam is not only dependent on the Snake River discharge but also, to some degree, on the confluence elevation at the Columbia River. The confluence elevation, in turn, is dependent on the forebay elevation at McNary Dam and the discharge of the Columbia River. Tabulations and plots of the confluence elevation and Ice Harbor Dam tailwater elevation are given in tables 1 through 3 and charts 1 through 5 of appendix A.

A tabulation showing Snake River discharge and the most likely maximum and minimum tailwater elevations is given below in table 5-1 and shown in figure 1. In determining the most likely maximum tailwater, a McNary forebay elevation of 340.0 feet mean sea level (fmsl) and a Columbia River discharge at McNary equal to 3.5 times the Snake River discharge were used. For the most likely minimum tailwater, a McNary forebay elevation of 337.5 fmsl and a Columbia River discharge at McNary equal to twice the Snake River discharge were used. (These multipliers, 3.5 and 2.0, were derived from comparisons of average monthly discharges of the Columbia and Snake Rivers for the period of 1928-1978.)

Table 5-1 - Most Likely Maximum and Minimum Tailwater Elevations		
Snake River Discharge (kcfs)	Ice Harbor Tailwater Elevation (fmsl)	
	Maximum	Minimum
20	340.6	338.6
40	342.0	340.7
60	343.6	342.7
80	345.2	344.5
100	346.7	346.1
120	348.1	347.5
140	349.4	348.8
160	350.6	350.1
180	351.8	351.3

#### 5.04. DEFLECTOR DESIGN.

##### a. Entrained Air in Physical Hydraulic Models.

Physical models of hydraulic structures are valuable tools for visualizing flow patterns, evaluating hydraulic performance, and estimating hydraulic conditions that will exist in a full-scale structure. However, air bubbles entrained within the spill flow of a physical model are not at the same scale as the model. They are very large compared to those that will be encountered in the full scale structure. As a consequence, the large buoyant force allows the bubbles to escape the flow much quicker in a model. The effects of this distortion show up when tracking the extent of an entrained air plume. The model plume is attenuated in length and in depth.

The value of hydraulic models in gas transfer processes lies in flow visualization and alternative comparison. An understanding of the flow conditions that

contribute to increased gas transfer provides a basis for assessing alternative designs in a physical model. For example, conditions that produce plunging flow conditions can easily be determined. Alternatives that avoid these conditions or modify flow patterns to something more acceptable can be identified.

b. Stilling Basin Flow Conditions with Spillway Deflectors.

Observations of sectional model tests with spillway deflectors installed indicated that up to six different hydraulic conditions could occur in the stilling basin for a given spill per bay. The resulting stilling basin condition was dependent on what the tailwater elevation was set at. Starting with a low tailwater elevation, the spillway flow would be launched by the deflector and plunge into the stilling basin. Usually, this condition was associated with the aeration of the underside of the nappe at the deflector. As the tailwater elevation was raised, the tailwater became high enough that a mixed skimming and plunging condition occurred, which has been termed unstable. With an even higher tailwater elevation, a point was reached where the spillway flow would only skim along the top of the tailwater. Eventually, the tailwater elevation would become high enough that the skimming flow would start to become an undular surface flow. The initial hump of the undular surface flow would move upstream towards the spillway with increases in the tailwater elevation. The undular surface flow would become an elevated hydraulic jump above the deflector. Finally, when the tailwater was high enough, the hydraulic jump would become a submerged jump on top of the deflector.

c. Size and Shape of Deflectors.

Model tests were conducted at the Waterways Experiment Station (WES) using a 1:40 scale sectional model of the Ice Harbor Dam spillway. Initially, a 12.5-foot-horizontal deflector was tested. Later, a 12.5-foot-horizontal deflector with a 15-foot-radius fillet between the deflector and the spillway surface was tested. The deflector with the fillet produced a better skimming flow condition in the stilling basin than the deflector without the fillet. In addition to providing better skimming conditions, a radius fillet should help reduce the risk for potential fish impact injuries. Testing also included a short, 4.2-foot deflector with an 8-foot-radius fillet. A comparison of the results for the two deflectors with fillets indicated that the short deflector had a much smaller range of tailwater elevations that produce skimming flow conditions. Thus, the 12.5-foot deflector with a 15-foot-radius fillet was selected.

d. Elevation of Deflectors.

Previous Ice Harbor spillway model studies of 1976 selected a deflector elevation of 336 fmsl. A major factor that influenced the previous model study efforts was that, at that time, the spillway was operated only to past river flows in excess of powerhouse capacity. Thus, a single tailwater elevation versus spill discharge relationship was examined in selecting the deflector elevation. Currently, the spillway

is operated to increase juvenile fish passage, which occurs during various levels of powerhouse usage, not just with full powerhouse flows. It should also be noted that a limited number of stilling basin flow characteristics were reported previously: "stable plunging flow;" "unstable zone (surging);" and "stable skimming flow." No upper limit of tailwater elevation was reported for the skimming flow condition.

Initial testing of the current sectional model at WES was conducted with the deflectors located at elevation 335 fmsl. The skimming limits, in terms of submergence (tailwater elevation minus deflector elevation), were plotted against the spill discharge per spill bay. The zone of good skimming flow was then overlaid with tailwater elevation curves for various powerhouse discharges. (A similar overlay is shown in figure 3 using the results, which are shown in figure 2, of model tests with spillway deflectors located at elevation 338 fmsl.)

The overlaid plots indicated that locating the deflectors at elevation 338 fmsl would provide a skimming condition in the stilling basin for spills of 5 kcfs per spill bay with the Bi-Op's targeting minimum Snake River discharge of 85 kcfs. Spill of 5 kcfs per spill bay relates to a total spill discharge of 45 kcfs (8 spill bays times 5 kcfs, plus the combined discharge from the 2 end spill bays of approximately 5 kcfs). However, for full powerhouse discharge (approximately 100 kcfs) with spill discharges of 25 kcfs (2.5 kcfs per spill bay) and 45 kcfs, there would be 2 and 1 feet, respectively, too much submergence for skimming flow conditions in the stilling basin. Since the range of submergence is not large enough to provide skimming conditions for all desired project operations, it was judged that it would be better to have the deflectors too low than to have them too high. This judgment is based on the belief that the hydraulic conditions when the submergence is slightly too high (starting into the undular zone) is better in terms of reducing TDG levels than the hydraulic condition when the submergence is slightly too low (the latter part of the mixed plunging/skimming zone).

Two other reasons support locating the deflectors at elevation 338 fmsl instead of a higher elevation. One reason is that at the higher powerhouse discharge levels (when there would be too much submergence) the spill discharge is a lower percentage of the total river discharge. A second reason is the importance of providing as much TDG reduction as possible for the higher percentage of spill scenarios because the following three items indicate that these scenarios are quite likely and very important: 1) uncertainties in the fish guidance efficiency estimates of the standard length turbine intake screens, which may lead to higher spill percentages to increase the project's fish passage efficiency; 2) possible 12-hour evening spill operations for juvenile fish passage, which would have higher spill percentages than full day operation; and 3) possible summertime spill for fall chinook juvenile migrates.

e. Short Extension of the Piers Adjacent to the Deflectors.

It has been observed in the models that spillway flows adjacent to the piers expand rather dramatically outward just downstream of the piers due to the deflectors. The expanding flow from both sides of a pier collide together, shooting a jet of water up into the air. A judgment has been made by U.S. Army Corps of Engineers (Corps) fishery biologists that this condition could be detrimental to juvenile fish being carried along within the spill next to the piers.

Model studies indicate that a deflector pier block prevents the rapid expansion and collision of the spill next to the pier. A deflector pier block is a structure that extends from the downstream nose of the spillway piers and sits on top of the deflector.

Each of the 7 pier blocks are 10 feet wide, the same width as the piers, and extend 6 feet 9 inches from the existing pier to the downstream face of the deflector. The top of the block is at elevation 350 fmsl.

f. Rock Debris Movement within the Stilling Basin.

Skimming flow produced by spillway deflectors causes a vertical eddy, which draws water back into the basin from the endsill. The eddy flow moves along the basin floor upstream to the spillway toe. This hydraulic action can pull rock debris from the tailrace region, downstream of the endsill, into the basin. Once the debris is pulled into the basin, it has a tendency to migrate to the toe of the spillway. Rock debris, which migrates to the toe beneath the deflectors forms circular moving cells. The location of the cells is dependent on proximity of the training wall, differences in adjacent spill gate openings, magnitude of the spill, and the hydraulic action caused by the spillway piers. The movement and intensity of the cells is directly related to the amount of spill. Though the movement of the debris cells is quite dramatic in the model it is difficult to determine what effects this action will have on the prototype basin.

Significant erosion has been found in two areas of the stilling basin at Lower Monumental Dam. Lower Monumental has had deflectors on six of its eight bays since 1974. It appears the erosion of the basin is related to hydraulic conditions created by discharge through adjacent deflector and non-deflector bays (bays 1 and 2, and 7 and 8). This erosion has been identified in the Lower Monumental Letter Supplement No. 1, *Spillway Stilling Basin Repair*, to Design Memorandum No. 10, *Spillway, Basis of Design* (being finalized at this time). This report will address the basin erosion and include a plan to identify the cause of erosion and method of repair. It will also identify alternatives for a long term solution. These alternatives will be evaluated using existing general and sectional spillway models.

Unlike Lower Monumental the Ice Harbor spillway has extended training walls which partially separate each of the two outside bays from the interior spill bays. These training walls extend downstream of the spillway piers about two thirds of the length of the stilling basin. Model tests of the Ice Harbor spillway indicate the existing training walls are long enough to prevent erosive activity of rock debris between a non-deflector bay to the outside of the training wall and a deflector bay to the inside of the training wall. However, a potential for rock debris to be pulled into the basin in the vicinity of the training walls was observed in the model. Most of the debris pulled into the basin near the training wall migrated around the end of the wall to the toe of the adjacent deflector spill bay. None of the debris remained at the end of the training wall.

Ice Harbor stilling basin conditions, with deflectors on the eight interior bays, are better represented by conditions within the Lower Granite stilling basin than those which occur at Lower Monumental. Inspection of the Lower Granite stilling basin confirmed large rock debris was being brought into the basin by hydraulic action caused by the deflectors. The basin showed signs of some erosion; however, no major concentrated erosion zones were found. Though uncertainty exists on how this material would effect the basin during large, long duration spill events; the moderate spill conditions that have occurred at Lower Granite since construction in 1975 have not resulted in any major damage. Thus, debris concerns associated with the installation of deflectors at Ice Harbor are not such that construction of deflectors should be delayed given the serious need to reduce TDG levels at Ice Harbor. However, the basin should be monitored closely after any major spills and results of the Lower Monumental Stilling Basin Erosion Study should be reviewed for possible application at Ice Harbor.

g. Energy Dissipation with Flood Discharges.

The energy dissipation performance of the stilling basin with flood discharges was examined in the sectional model. Flood discharges of 42 kcfs/bay and nearly 85 kcfs/bay (which correspond to 420 kcfs - standard project flood; and 850 kcfs spillway design flow) were looked at both with and without deflectors installed at elevation 338 fmsl. For all conditions, there appeared to be very strong downstream velocities at the top of the endsill. For the runs with the deflectors in place, it appeared that the tailwater surface was less turbulent downstream of the endsill than for the runs without deflectors installed. It is suspected that the deflectors help dissipate energy similar to what baffle blocks do. There was a very strong, tight vertical eddy just downstream of the deflector. It is likely this eddy is helping to dissipate some of the energy. However, this strong vertical eddy was also violently moving the rock debris around at the toe of the spillway. It was concluded that the energy dissipation in the stilling basin with deflectors installed would be as good as, or better than, without deflectors.

## 5.05. DEFLECTOR INFLUENCE ON NAVIGATION.

### a. Existing Conditions.

Generally, it is more difficult to exit from the downstream side of a navigation lock than to approach it. This is because the relative flow past the towboat traveling upstream is faster and thus provides more effective steerage. At Ice Harbor Dam, navigation conditions downstream of the project are sometimes complicated by powerhouse discharges flowing diagonally across the river and into the navigation channel. The cross channel flow requires tow operators to steer an angled course (crab) to stay in the channel. Under extreme conditions, some operators split larger tows into two as they pass Ice Harbor Dam.

Model studies were conducted by the Bonneville Hydraulic Laboratory in 1981 and 1982 to address navigation concerns at Ice Harbor Dam. The study was conducted to determine the feasibility of correcting or improving the navigation problems resulting from cross current flows from the powerhouse. Various forms of guidewall extensions and additional channel excavation were explored. None of the tested modifications succeeded to the satisfaction of the tow operators in correcting conditions downstream from the lock. Study results were reported in Technical Report No. 192-1, 1983, *McNary Reservoir Navigation at Ice Harbor Dam Snake River, Washington*.

The 1983 model report shows the tendency of flow to sweep diagonally across the river channel from the powerhouse towards the navigation channel. This results in a strong cross flow downstream of the navigation lock guidewall. The effect was strongest during maximum powerhouse discharge of 100 kcfs with no spill. At higher river discharge levels, the added spillway discharge acted to buffer and reduce the angle of the flow approaching the navigation channel and consequently the degree of cross flow.

Recently, tow operators have experienced difficulty approaching and leaving the downstream end of the Ice Harbor navigation lock during high flow conditions. The alternate spill pattern, which was implemented during the 1996 spill season for nighttime spill for the purpose of reducing TDG levels (see table 2), made it difficult for some tow operators to enter and exit the navigation lock. When the alternate spill pattern was used, spill discharges exceeding 80 kcfs resulted in high velocity cross channel flows and strong wave action downstream of the navigation lock guidewall. These conditions, at times, forced tow operators to wait until the spill pattern was changed to the standard pattern (used for daytime adult fish passage) before locking through. During the 1996 spill season, there were no reported problems associated with the standard spill pattern though, even when spill levels exceeded 100 kcfs and total river discharges reached as high as 210 kcfs.

b. Projected Conditions with Spillway Deflectors.

Preliminary model investigations at WES have shown the installation of deflectors at Ice Harbor will result in higher cross current velocities and greater surface turbulence. These conditions may be similar to those flow conditions experienced when spilling according to the alternate pattern and will likely affect barge traffic to some degree.

The effect of deflectors on cross flow currents downstream of the navigation lock were evaluated using the new Ice Harbor 1:55 scale general model at WES. Conditions downstream of the guidewall were evaluated for total river flows of 150 kcfs (90 kcfs powerhouse discharge and 60 kcfs spill discharge) and 225 kcfs (90 kcfs powerhouse and 135-kcfs spill). Figures 7 through 10 show velocity measurements recorded for both the base conditions and the 8 spillway deflector conditions. With deflectors installed on the center 8 spill bays, the cross channel current flows into the navigation channel approximately 400 feet downstream of the guidewall and did not vary significantly from base conditions at 150 kcfs. However, mid-river channel velocities directed downstream and toward the navigation channel increased by as much as 50 percent. Mid-river channel flows for the base condition ranged from 6 to 8 feet per second (fps), while flows with deflectors ranged from 9 to 12 fps. Because of model limitations, it was not possible to evaluate the effect of deflectors on cross channel flows further downstream. Previous model studies indicate cross flows to the navigation channel approximately 600 feet downstream of the guidewall were 6 to 7 fps at river flows of 150 kcfs. It has been estimated that these flows may increase to as much as 10 fps with the installation of deflectors. The velocity of cross channel flows for the base condition of 225 kcfs ranged from 6 fps, 400 feet downstream of the guidewall to 12 fps in mid-river. These conditions were very similar to deflector flows at 150 kcfs total river discharge. The 8 spillway deflector condition with 225 kcfs total river flow increased cross channel velocities of 5 and 6 fps to 6 and 7 fps at a point 400 feet downstream of the lock guidewall. The deflectors increased the mid-river flows from a range of 8 to 12 fps to a range of 10 to 16 fps. This is likely to increase cross channel flow velocities by 2 to 4 fps, 600 to 800 feet downstream of the guidewall.

5.06. DEFLECTOR INFLUENCE ON ADULT FISH PASSAGE CONDITIONS.

a. General.

Hydraulic conditions downstream of the stilling basin and in the vicinity of the fishway entrances are critical to adult fish passage. An evaluation of tailrace conditions was required to determine the optimum number of spillway deflectors and to develop spill patterns that would provide the best hydraulic conditions for adult fish passage.

b. Tailrace Evaluation.

A newly constructed, 1:55 scale general model of Ice Harbor Dam was used to evaluate deflectors and potential impacts on adult fish passage. In addition, extensions to the existing training walls between spill bays 1 and 2, as well as 9 and 10, were also evaluated as a means of improving adult passage conditions. The model reproduced the 6-unit powerhouse, 10-bay spillway and stilling basin, fishway entrances, navigation lock and guidewall, and the riverbed 2,500 feet downstream of the structure. The 12.5-foot deflectors were set at elevation 338 fmsl and the training walls were extended approximately 60 feet to the endsill of the stilling basin. Tailrace conditions were evaluated and observed in the model for total river flows of 50 to 150 kcfs. Fishway attraction flows were set at 700 cubic feet per second (cfs) each for the south powerhouse entrance, the north powerhouse entrance (NPE), and the north spillway entrance (NSE). Tailwater elevations ranged from 344 to 350 fmsl. Observations included 6, 8, and 10 spill bay deflectors performance with and without extended training walls. Evaluations were based on criteria presented in section 5.06.c., below.

Table 3 shows test conditions observed and the spill pattern, which appeared to provide the best possible tailrace conditions for adult passage. Figures 11 through 21 identify general flow patterns associated with these test conditions. Because of an accelerated design and construction schedule for deflectors at Ice Harbor, detailed velocity measurements of test conditions could not be completed in time for publication of this design memorandum. Velocity measurements for both interim and final design conditions will be made and included in a letter supplement to this report.

c. Evaluation Criteria.

Adult fish passage conditions were evaluated in the Ice Harbor Dam's general model by Corps biologists and engineers as well as experts in adult passage from the National Marine Fisheries Service (NMFS) and the University of Idaho. The purpose of this evaluation was to determine the optimum number of spillway deflectors and to develop a spill pattern that provides efficient fish passage conditions.

Criteria developed by Junge and Carnegie (1972) for the Fish Commission of Oregon were used as general guidelines. These guidelines identify visual cues for both desirable and undesirable flow conditions for adult fish passage and are listed below.

(1) Desirable Spillway Characteristics for Adult Passage.

(a) Undisturbed and uninterrupted flow from the fishways should be directed downstream. It is most important when high flows from the spillway are competing with flow from the fishway.

(b) There should be sufficiently high velocities downstream from the spillway to prevent fish from approaching the spillway directly.

(c) There should be a velocity barrier angling towards the fishway entrances. A white water lead or series of standing waves may be an indicator of the presence of such a barrier.

(d) When total spill volumes are insufficient to prevent fish from approaching the spillway, it is generally recommended that the spillway discharge be concentrated on the end spill bays so fish are attracted to the vicinity of the fishways at either side of the spillway.

(2) Undesirable Spillway Conditions for Adult Passage.

(a) When relatively small volumes of water are spilled, such spills should not be released at the central spill bays. These spills will attract fish to an area remote from the fishway entrances and could cause delays. Small spills should be concentrated near the end spill bays to provide attraction flows near the fishway entrances.

(b) Excessive spill from the end spill bays adjacent to a fishway (particularly near the navigation lock wall) can cause severe turbulence directly below the fishway entrances. Such turbulence below a fishway can seriously block passage.

(c) When excessive spill from spill bays adjacent to the powerhouse converge with large flows from the powerhouse, standing waves may be formed directly below the fishway entrance between the spillway and the powerhouse. This condition may create a hydraulic barrier preventing access to the fishway entrance.

(d) During high spills, strong currents may be directed sharply toward the shore, below the fishway entrances, creating waves breaking against the navigation guidewall. These higher discharges may also distort the white water lead on the powerhouse side of the spillway, directing fish beyond the main fishway entrance and toward the turbine boil.

(e) Excessive downstream velocities along the shore, below the fishway entrance, may prevent fish from reaching the fishway. Velocities in excess of 7 or 8 fps for an extended distance are not desirable.

(f) High discharges from interior spill bays that have deflectors can create large eddies below the fishways. This will often result in upstream flows along the fish ladder wall and navigation guidewall. Under severe conditions, these upstream flows may continue almost to the fishway entrance canceling out the attraction flows from the fishway.

d. Baseline Conditions - No Deflectors.

Spill discharges for baseline test conditions were in accordance with the standard fish passage spill pattern. An eddy was observed downstream of NSE along the wall of the north shore fish ladder for all baseline tests. The length, width, and intensity varied with spill discharge. With 25-kcfs spill, the attraction flow from the north entrance would typically meander to the south along the outer edge of the eddy and merge with the discharge of spill bay 10 (figure 11). Higher discharges of 45 to 60 kcfs increased the intensity of the eddy and created a cross flow below the NSE that would force the entrance flows across and into the stilling basin below spill bay 10 (figure 12).

Flow from the NPE was influenced by the upwelling of powerhouse discharge. The attraction flow from this entrance was typically directed downstream along the outer edges of discharge from spill bay 1.

e. Six Deflectors - Spill Bays 3 Through 8.

The tailrace conditions observed during tests with the six spillway deflectors were similar to the base conditions. With 25-kcfs spill, a slow back eddy was noticed downstream of the fishway entrance along the wall of the north shore fish ladder. The eddy had little influence on the attraction flows of the NSE. This eddy was present under all conditions, it varied in width, length, and intensity depending on spill discharge and gate operation (figures 13, 14, and 15). With increased spill, the eddy became more intense and moved upstream closer to the NSE creating a cross current that directed the entrance flow across the end of the stilling basin. The NPE attraction flows were also similar to the base conditions. When discharging 60 kcfs, an intermittent eddy would form downstream of spill bay 1 and the NPE.

In general, adult fish attraction flows compared well to the base conditions for all spill flows up to 60 kcfs. However, higher discharges were needed through non-deflector spill bays 2 and 9 to provide the best conditions near fishway entrances and to prevent large slack water regions that could contribute to predation of juveniles. The spill pattern required as much as 45 percent of the total spill flow through non-deflector spill bays, significantly reducing the potential for minimizing TDG levels.

f. Eight Deflectors - Spill Bays 2 Through 9.

Flow patterns with deflectors in spill bays 2 through 9 did not change much from the base conditions with a discharge of 25 kcfs. A mild eddy was present downstream of the NSE, along the north wall of the fishway. This eddy extended approximately 200 feet downstream of the basin endsill (figure 16). Higher spill discharges of 45 and 60 kcfs resulted in eddies that were narrower and more intense than the base condition (figures 17 and 18). Upstream velocities along the north fishway wall were higher and the eddies created cross flows in front of the NSE. The

entrance attraction flows appeared to be assimilated into the eddy or forced into the stilling basin below spill bay 10.

Entrance flows from the NPE were influenced by the upwelling of powerhouse flows, but generally swept diagonally across the end of the stilling basin below spill bay 1. A mild eddy would occasionally develop and disperse downstream of powerhouse unit 6 and spill bay 1. The occurrence of this eddy however, does not appear to be an impediment for adult fish passage.

Some of the discharge from non-deflector spill bays 1 and 10 was drawn around the existing training walls to the spillway toe beneath the adjacent deflector spill bays. This condition was prominent for all spill conditions, but would not seem to negatively impact adult fish passage. However, it may potentially increase the generation of TDG by pulling high concentrations of entrained air from spill bays 1 and 10 to a depth below the deflectors. It was also noted that powerhouse flows could be drawn into the basin by reducing or restricting the discharge of spill bay 1. This type of operation may assist in diluting the saturated spill discharge.

Extending the training wall between spill bays 9 and 10 pushed the north side eddy further downstream, away from the NSE. It also eliminated the cross flow below the entrance and prevented the attraction flow from entering the basin below spill bay 10. Adult fish passage conditions were improved for all spill discharges up to 60 kcfs (figures 19, 20, and 21). The extended training wall between spill bays 1 and 2 prevented the diagonal flow across the stilling basin and the formation of eddies below the NPE and spill bay 1, but did not seem to greatly improve the adult fish passage conditions below this entrance. The extensions also prevented the non-deflector spill bay discharge from being pulled into the basin below the deflector spill bays and may provide additional benefits in reducing TDG.

A uniform spill discharge through the 8 deflector spill bays with approximately 2,000 cfs through the end spill bays provided the best tailrace conditions both with and without the extensions. This pattern reduced the size of the north side eddy and minimized slack water in the tailrace.

g. Ten Deflectors - All Spill Bays.

Deflectors across all 10 spill bays with an extended training wall between spill bays 9 and 10 appeared to provide adequate adult fish passage conditions for all spill discharges to 60 kcfs and total river flows of 150 kcfs. A detailed investigation and documentation of flow conditions for 10 deflectors has not yet been completed. However, it may be possible to maximize the dissolved gas reduction capability and provide the best entrance conditions for both the NPE and NSE by optimizing the deflector elevation in spill bays 1 and 10.

A preliminary look with temporary deflectors in spill bays 1 and 10 and an extended training wall between spill bays 9 and 10 seemed to provide very similar tailrace conditions to the 8 bay deflector test with training wall extensions. The fishway entrance conditions are greatly influenced by the elevation of the deflectors as well as the discharge through the outer spill bays. A more detailed study is needed to determine the optimum elevation of deflectors in spill bays 1 and 10 and to identify the best possible spill pattern.

h. Summary.

The 1976 Ice Harbor deflector model study (referenced in section 4.04.b.) indicated the best attraction flows existed at the fishway entrances when deflectors were installed in bays 3 through 8. It was also noted that the reduction in gas supersaturation would not be as effective as other deflector combinations. To provide adequate passage conditions, the six deflector arrangement required high discharges through the non-deflector bays 2 and 9. It also left 4 of the 10 spill bays without deflectors. The 1976 study focused primarily on involuntary spill operations and evaluated flow conditions for total river flows of 160 kcfs and greater. Among the reasons for not installing spillway deflectors following this study, were deflectors had been installed on the three Snake River dams upstream of Ice Harbor and Ice Harbor Dam had increased its powerhouse capacity by expanding from three turbine units to six. In addition, the schedule for adding turbine units to the upstream projects had been accelerated.

The objective of the most recent model study was similar to the 1976 study with the exception of the river flows considered. This study evaluated flow conditions most likely to influence adult passage. Fish ladder counts indicate the movement of adult fish in the Snake River system decrease dramatically as flows begin to exceed 150 kcfs. Therefore, this model study focused on total river flows less than 150 kcfs, and spill discharges that ranged from 25 to 60 kcfs. Tailrace conditions were observed with deflectors on 6, 8, and 10 bays.

Both regional and Corps biologist and engineers determined deflectors should be installed on bays 2 through 9. Impacts to adult passage would be no worse than existing conditions for spill flows up to 45 kcfs. Though spill discharges of 45 to 60 kcfs resulted in conditions which appeared worse than the existing no-deflector conditions, it was determined these conditions would be acceptable as an interim operation.

Extended training walls in addition to the 8 spillway deflectors were also observed. An extension of the north training wall (between spill bays 9 and 10) greatly improved flow conditions below the NSE. Conditions appeared better than existing no-deflector conditions for all spill flows up to 60 kcfs. Extending both the north and south training wall may allow deflectors to be installed in spill bays 1 and 10 without negatively impacting adult passage. It was determined that an extension to the north

training wall should be constructed following the installation of the initial 8 spillway deflectors. Further model studies and evaluations are needed to determine the benefits and need for extending the south side training wall and additional deflectors in spill bays 1 and 10.

A spill pattern designed to provide the best possible adult passage conditions within the tailrace is included in table 4. This table has been developed as a general guide and will likely require adjustment following prototype evaluation. This pattern should be followed for daytime spill operations (06:00 to 18:00 hours) when most of the adult fish move through the system. For the most effective reduction of TDG, the spill should be evenly distributed across the eight deflector bays, with no spill through bays 1 and 10. This pattern should be implemented during nighttime operations (18:00 to 06:00 hours) when there is little adult fish passage through the fishways.

Although the focus of the latest model study was primarily on adult passage conditions, spill patterns were also evaluated for potential impacts on juveniles. Large eddies and slack water regions were identified as possible regions for predators. The spill patterns were adjusted to provide the best possible adult passage conditions while reducing potential areas of predation.

#### 5.07. CONCLUSIONS AND RECOMMENDATIONS.

Spillway deflectors at Ice Harbor Dam should be 12.5 feet long with a 15-foot-radius fillet between the deflectors and the spillway. The deflectors installed on the 8 central bays should be located at elevation 338 fmsl. Hydraulic model tests indicate the existing training walls are long enough to prevent erosive rock debris movement in the vicinity of the training wall. However, there is the potential for erosion at the spillway toe due to rock debris movement caused by the hydraulic action of the spillway deflectors. The studies have also shown that energy dissipation in the stilling basin under flood discharges will be as good as the existing energy dissipation.

Preliminary model investigations at WES indicate that installation of deflectors at Ice Harbor will result in higher cross channel velocities and greater surface turbulence near the end of the downstream navigation lock guidewall. These conditions are likely to make it more difficult for barge traffic to navigate into and out of the lock.

General observations of flow patterns and velocity measurements were used to assess the potential impacts of spillway deflectors on adult passage conditions. Because of the critical need to minimize the adverse impacts of TDG, Corps biologist and engineers as well as adult fish passage experts from NMFS and the University of Idaho have recommended the immediate installation of deflectors on spill bays 2 through 9. After the eight deflectors have been installed, the Corps of Engineers Fish Passage Plan must be revised to include the new spill pattern shown in table 4. This spill pattern should be implemented during daylight hours. Nighttime spill should be

evenly distributed over the deflector bays with no spill discharge through the two non-deflector bays.

It is also recommended to continue evaluation of: 1) navigation conditions with spillway deflectors installed; 2) spillway deflectors in spill bays 1 and 10; 3) extensions to the existing training walls; and 4) potential modifications to the north shore fishway entrance. These modifications will be evaluated in the Ice Harbor 1:55 scale model. Any further recommendations based on these evaluations will be made in a supplemental letter to this design memorandum.



## SECTION 6.0 -STRUCTURAL DESIGN CRITERIA

### 6.01. DESIGN CRITERIA AND CODES.

- a. Engineering Manual 1110-2-2200, *Gravity Dam Design*, 25 September 1958.
- b. Engineering Manual 1110-2-2104, *Strength Design for Reinforced-Concrete Hydraulic Structures*, 30 June 1992.
- c. American Concrete Institute (ACI) 318-95, *Building Code Requirements for Structural Concrete*.
- d. American Institute of Steel Construction (AISC), *Manual of Steel Construction, Allowable Stress Design*, 9th Edition.
- e. American Welding Society (AWS), ANSI/AWS D1.1-96, *Structural Welding Code - Steel*.

### 6.02. SPILLWAY DEFLECTORS AND SHORT PIER EXTENSIONS.

Reinforced concrete was selected as the preferred material to construct the spillway deflectors and short pier extensions adjacent to the deflectors. Structural steel was also considered for its ability to be installed without dewatering. But, due to the unknown magnitude of stress ranges and vibration frequencies to which the steel structure would be subjected, the massive and proven concrete deflector was selected.

The following load cases were considered in the design of the spillway deflectors and short pier extensions:

- a. Case one - Construction condition: gravity load without hydraulic loads.
- b. Case two - Normal operation condition: minimum tailwater at elevation 335 feet mean sea level (fmsl) with and without ice loading of 10,000 pounds per foot at elevation 334 fmsl.
- c. Case three - Normal operation condition: maximum tailwater at elevation 375 fmsl, adjacent spill bays assumed to be spilling.
- d. Case four - Spill condition: tailwater at elevation 338 fmsl, hydraulic pressure of 5,300 pounds per square foot (psf) applied to the complete top surface of the deflector except for the last (downstream) 3.5 feet. The hydraulic pressure on this downstream portion of the deflector varies linearly from 2,500 psf at the downstream edge to 5,300 psf 3.5-feet upstream. This loading is for a spill discharge of

85,000 cfs/bay and is based on results of spillway deflector model tests for McNary, Lower Monumental, and Lower Granite Dams.

e. Case five - Normal operation condition with earthquake: tailwater at elevation 348 fmsl and a seismic acceleration of 0.10g.

f. Case six - Hydraulic pressure in the interface immediately after spill has stopped: tailwater at elevation 338 fmsl and assuming the hydraulic pressure in the interface of the existing ogee and the deflector is linear from the tailwater pressure at the bottom edge to 5,300 psf at the top edge.

For load cases two, three, four, and five the hydraulic pressure in the interface was considered or neglected to determine the worst case loading. Load cases four and six were the critical load cases requiring numerous steel anchors acting in tension and shear friction to resist the imposed loads.

## SECTION 7.0 - CONSTRUCTION METHODS

### 7.01. GENERAL.

Spillway deflectors are to be constructed on the interior eight spill bays of the Ice Harbor Dam's Spillway Dam. Each spill bay is 50 feet wide, separated by a 10-foot pier. The spillway deflectors (plate 3) form a reverse ogee and redirect the spillway flow from plunging deep into the stilling basin to a more surface-oriented, horizontal direction. The top surface of the deflector is a vertical curve with a radius of 15 feet that transitions from the spillway slope to a horizontal surface. This horizontal surface is about 1 to 9 feet below normal tailwater elevations.

The deflectors will be concrete structures, anchored to the spillway slope. The anchor design provides for stability against the tensile force on the deflector from hydraulic uplift forces in the interface, between the new concrete and the sloped spillway surface. The anchors also provide shear resistance for the deflector.

### 7.02. DEWATERING.

#### a. General Considerations.

Spillway deflectors have been constructed at several projects. In the early 1970's, spillway deflectors were constructed at Lower Monumental Dam. The last deflector installation completed by the U.S. Army Corps of Engineers (Corps), Walla Walla District was for 18 spillway bays at McNary Dam in 1975. Several dewatering schemes were considered for the Ice Harbor Dam project. However, no dewatering method will be specified in the contract. A summary of the possible schemes follows.

#### b. McNary Floating Bulkhead Scheme.

Two floating bulkheads were designed and constructed for construction of the McNary spillway deflectors. These 70-ton units were provided as Government-furnished property to General Construction Company for the deflector construction contract. The bulkheads are a three-chambered unit that span the full spillway spill bay and seal against the spillway surface and the pier walls. The unit was submerged by filling the chambers with water. Attached to the bulkheads is an innovative seal system to prevent large volumes of water from entering the placement area. Anchor bolts were installed to secure the end walls as the enclosure was dewatered. Upon completion of the McNary work, the bulkheads were transported to Ice Harbor Dam and stored on the left shore upstream of the dam.

Based on the excellent performance of the bulkheads at McNary Dam, the ideal situation would be to rehabilitate the existing bulkheads and furnish them to the Ice Harbor Dam's deflector contractor. An alternate situation would be to fabricate new

bulkheads of the same design and furnish them to the deflector contractor. Unfortunately, there is not sufficient lead time to initiate this work. Furthermore, because of the uncertainty in the condition of the existing bulkheads, they will not be furnished to the contractor for use at Ice Harbor Dam.

c. Navigation Lock Floating Bulkhead Scheme.

Each navigation lock for the Snake River dams and McNary Dam is equipped with a floating bulkhead. This bulkhead is used to dewater the navigation lock and may be positioned either at the upstream or downstream end of the navigation lock. The floating bulkheads span 88 feet at a depth of 23 feet. They are designed to be interchangeable between projects. With the addition of several steel members, two floating bulkheads may be utilized to dewater three spillway spill bays simultaneously. Details of the additional members are shown on plates 6 through 19.

Required modifications are necessary to extend the height of the bulkhead for this deeper application. In addition, seals must be provided at bearing points and braces provided to support the bulkhead when the placement area is dewatered. Upon contract award, immediate fabrication of the training wall seals, couple seal and brace, end wall and brace, and the base table is necessary. Each of these members must be installed and anchored underwater using divers. Only then can the floating bulkheads be positioned over the base table and against the seal members and subsequently sunk into position.

Late in the design phase, it was decided to extend the piers. This change practically eliminates the use of the navigation lock floating bulkheads as a possible contractor option. The new configuration makes possible a simpler forming/bulkhead system and eliminates the major cost of fabricating bulkhead accessories.

d. Other Formwork Systems.

Several other schemes may be possible for deflector construction. The contractor may fabricate a relatively simple form against which concrete may be placed.

e. Specifications.

The contract documents will provide detailed criteria for a dewatering system without specifying the type of dewatering system.

7.03. ANCHOR INSTALLATION.

a. General Considerations.

During the period of form/bulkhead fabrication, holes for anchors must be installed. The short work window and possible access problems encourage the drilling

of anchor holes prior to setting formwork/bulkheads and unwatering. The stability of the deflectors is wholly dependent on properly installed anchors. Approximately one third of the anchors are located in the upper radius zone and the remaining two thirds anchor the more bulky lower section. Anchor depths average approximately 6.5 feet.

b. In-Water Drilling.

Under land-based conditions, holes of this type would be drilled with a rotary percussion drill (track drill) in a very short period of time. However, over water, the equipment must be mounted on a barge. Most likely, two drills will be mounted on a barge and drilling into the spillway face controlled by using pre-fabricated steel templates. Depending on the dewatering scheme, a certain number of anchors must be drilled before dewatering can commence. The remaining holes can be drilled at other spillway bays while concrete operations proceed. The total volume of drill cuttings, which is in the form of coarse sand, is approximately 10 cubic yards (10,000 linear feet of 3-inch diameter drill hole). Turbidity will be controlled by specifying a limited number of nephelometric turbidity units above background levels, measured some distance downstream of the work area.

c. Possible Underwater Bar Installation.

Specifications will not permit bar splices in the anchors. Consequently, each anchor must be a single unit. Since the clearance between the bulkhead and the spillway face is limited in the lower zones, anchors must be installed prior to setting the bulkhead. Specifications will allow replacement of the bars and upon dewatering, the bars may then be grouted in dry holes.

7.04. EXCAVATION METHODS.

a. General Considerations.

Concrete excavation is limited to two areas in the spillway. The main area of excavation is the upper radius of the deflector where a 7 foot length and up to 2 foot depth of concrete must be removed for the full width of the spillway spill bay. The volume of concrete to be removed per spillway bay is approximately 26 cubic yards. In all cases, the radius concrete removal will be done within the work area enclosure and completely removed from the placement area. It is anticipated that the contractor will do removal after placement of the lower lift of concrete. This concrete provides a working platform to access the removal area. Other areas of concrete removal are minor areas where form and bulkhead supports are founded against the spillway structure. These areas could be excavated by divers using chipping guns. So far as practical, the extricated concrete will be collected and removed from the stilling basin.

b. Drilling/Removal Methods.

Several methods of concrete removal in the upper radius are available to the contractor. Drilling a pattern of holes and fracturing the concrete using hydraulic splitters is a very feasible method of concrete removal. If large equipment can access the area, the use of a hydraulic hammer may be possible. Both methods are routine excavation methods using readily available equipment. While not likely, the contractor may seek approval to drill the area and split the concrete using very light explosives. This option is more attractive for removal of concrete to a greater depth. Blasting operations would be in dry conditions using blast mats.

7.05. CONCRETE PLACEMENT.

Concrete for the spillway deflectors will be placed by conventional (in-the-dry) methods.

The design of the deflector requires that the top surface, which is subject to the high velocity of spillway discharges, be a superior quality concrete, capable of long-term performance. The concrete below this "topping," forming most of the concrete volume, need only be a conventional quality concrete.

Cleaning and roughening of the spillway surface must be done prior to concrete placement. The area against which concrete is to be placed will be cleaned with a high pressure water jet. A unit capable of up to 10,000 pounds per square inch (psi) may be necessary to provide adequate cleaning and the required amplitude of 1/4-inch roughness.

a. Concrete Plants.

A major consideration in planning concrete placement operations is the time that may elapse from the initial mixing of the concrete to final placement. This is especially true when complex concrete mixtures containing several critical admixtures are used in applications where the mixture workability is a key factor in a successful placement. Generally, on- or near-site batch plants are preferred for placements where time delays are likely. Relatively sophisticated batch plants in the Tri-Cities, WA (Pasco, Richland, and Kennewick) are capable of providing concrete in the required timeframe. Given the proximity of sophisticated ready-mix concrete plants, it is unlikely that the contractor will elect to batch materials onsite, much less mobilize a floating operation.

b. Conventional Placement Methods (In Dry).

Concrete will be delivered to the placement area by transit mixer. The concrete pump will most likely be located on the top of the dam near the spill bay under construction or on the tailrace deck next to the powerhouse. Pumping concrete from

the top of the dam presents several problems. Negative pressures from pumping concrete to a lower elevation can prevent the continuous flow of concrete. The specifications will allow drop pipes to be used so long as a collection hopper is used at the base of the drop line and measures taken to prevent the segregation of concrete. Pumping from the tailrace deck eliminates most of the negative pressure problems; however, it requires that the pumpline be installed across the spillway bays.

Placement of the concrete into the forms will be done in the conventional manner of placing pumped concrete. Concrete will be placed continuously in approximately 3-foot lifts for a total of approximately 200 cubic yards. Similar operations at Ice Harbor Dam using concrete batched near Richland, WA required 8 transit mixers and 10 hours to complete.

c. Underwater Placement Methods.

Much consideration was given to placement of the stage 1 concrete, the concrete below elevation 336, by underwater methods. This method would not require as extensive a bulkhead since full dewatering would not be required. However, the critical need for bond of concrete to the anchor bars and to the existing spillway surface eliminated this method from consideration. Placing concrete underwater presents a number of uncertainties that raise the level of risk for this method to an unacceptable level.

d. Superior Quality Top Surface.

Concrete having superior quality is required for the top 2 feet of the spillway deflector. Such quality is necessary to provide a surface that will withstand the erosive forces of high velocity flow. Concrete will be designed to produce approximately 750 psi flexural strength at 28 days. To provide toughness performance, a residual strength factor ( $R_{10,30}$ ) will be specified to be 75. This factor assures that the mixture will perform after initial cracking of the material. A silica fume admixture and appropriate water reducing admixtures will be used in these mixtures. Each spill bay is estimated to require 30 cubic yards of this mixture. The mixture will be applied after saw-cutting and excavating the radius section, installing anchors and reinforcement, and preparing the surface.

The contract will allow two methods for placement of this superior quality concrete. One method is to install screed rails having the radius shape of the top surface at appropriate intervals. Concrete must be placed from the bottom up using the screed rails as a finishing template and placing the concrete against temporary holding forms. This method has been used many times to form similar shapes.

The other alternative is to place the concrete by pneumatic methods, shotcrete, using piano wire guides. Wire guides are installed longitudinally to outline the shape of the surface. Wet-mix shotcrete is placed, from the top down, covering the

wires. The shotcrete is then manually trimmed and shaped to the wire outline. This method has been used several times to cast spillway caps for dams.

e. Contraction Joints.

Each spillway bay at Ice Harbor Dam contains a contraction joint in the center of the bay. The deflectors must also contain a joint to accommodate annual volume changes. Since concrete placement will be done during cold weather, later warming may create serious expansion problems such as shear failure of the concrete anchors. Without the inclusion of expansion joints, the deflector will crack and the surface adjacent to the crack will spall creating a serious erosion problem. Similarly, the interface between the spillway pier and the spillway bay results in a re-entrant corner that will crack. Providing a joint at these locations is necessary to prevent significant erosion.

The major problem with joints is that, when using conventional methods, three separate concrete placements are necessary to construct the entire deflector. The specifications will allow joints to be installed concurrently with the placement of concrete so that the number of placements can be reduced to two. Rigid joint materials can be placed in the proper location and concrete placed on either side. This construction process has been used in other projects. An alternate method is to sawcut the joint through a pre-placed tube. Polyvinyl chloride pipe can be embedded in the deflector concrete to provide entry points for the wire saw. The specifications will provide requirements for such activity.

7.06. DIVING OPERATIONS.

As with any underwater construction operation, a major consideration is the utilization of divers and support staff and equipment to perform underwater construction tasks. A dive team can consist of up to 10 people if 3 or more divers are required in the water at any one time. The Corps, Engineer Manual 385-1-1, *Safety and Health Requirements Manual*, requires surface supplied air for contract diving operations based on the type of diving operations that will be required. Diving operations on this job will require surface supplied air and a decompression chamber.

## SECTION 8.0 - ENVIRONMENTAL EFFECTS AND COMPLIANCE

### 8.01. ENVIRONMENTAL EFFECTS.

Construction of the spillway deflectors and training wall extension(s) would have only minor environmental effects. Construction would have minimal impacts on aquatic resources in the vicinity of the dam. No important fish habitat would be disturbed by the construction. Fish and other organisms in the river would easily avoid the construction activities. Any fish trapped in the work area would be released back into the river. There is the possibility that high river flows during the construction period could force the U.S. Army Corps of Engineers (Corps) to spill water over the construction area on the spillway. Fish caught up in the spill may strike the exposed anchors and bulkhead support structures (if the bulkhead with "table" method is being used) and be injured.

Construction activities would not impact wildlife use at the dam. Construction activities would take place when birds are not nesting. Any birds in the area would easily be able to avoid the work activities.

Operation of the spillway deflectors is expected to decrease total dissolved gas (TDG) when up to 60 thousand cubic feet per second (kcfs) of water is spilled, which could improve fish passage efficiency for salmon with little or no change in impacts to other aquatic organisms. At spill higher than 60 kcfs, the deflectors would be less effective at reducing TDG. Dissolved gas levels are of concern because gas supersaturation can lead to the development of gas bubble "disease" in fish and aquatic organisms. This condition can produce a variety of signs and physiological changes that are often fatal. Adult salmon are more susceptible to the effects of TDG supersaturation than juveniles due to their more developed organs. High gas saturation levels may also cause food organisms for juvenile salmon to involuntarily float away from salmon rearing and staging areas.

Spill at Ice Harbor Dam causes TDG supersaturation that frequently exceeds the established Washington water quality standard and Federal water quality criteria of 110 percent of barometric pressure, although, in recent years, the Corps has been allowed by the state to produce TDG up to 120 percent under temporary waiver for endangered species considerations. Total dissolved gas as high as 138 percent have been recorded immediately below the dam during spills greater than 60 kcfs. Total dissolved gas concentrations above 120 percent are considered lethal and lead to death or chronic physiological stress in juvenile salmon with enough exposure time; therefore, the dam is supposed to be operated such that TDG does not exceed 120 percent. However, adult salmon are negatively affected at TDG below 110 percent while TDG of 115 percent can be lethal. The Corps has estimated that installing deflectors at Ice Harbor Dam may reduce TDG by 5 to 10 percent at the current spill

cap level of 25 kcfs. If the deflectors are able to reduce TDG closer to between 110 and 115 percent, adult and juvenile salmon survival could be increased.

Ice Harbor Dam has two fish ladders to provide upstream passage for adult salmon migrating upstream to spawn. The entrance to the north ladder is adjacent to the north side of spill bay 10 while the south ladder entrance is adjacent to the south side of spill bay 1. Since adult salmon are attracted to strong flows, the Corps provides attraction water at the entrance of each ladder to help the adults find the ladders. Operation of the spillway deflectors may impact adult salmon passage conditions. The water moving over the deflectors may pull flows from the powerhouse over toward the stilling basin, creating a lateral flow across the downstream face of the dam. This lateral flow could produce turbulence that may confuse adult fish and discourage them from entering the fish ladders. However, model studies indicate operation of the deflectors would not create adult fish passage conditions worse than existing conditions. Extending the training wall between spill bays 9 and 10 may help reduce the turbulence and direct adult fish to the fish ladder.

The impact of the spillway deflectors on passage conditions for juvenile salmon going through the spillway is unknown. The stilling basin at Ice Harbor Dam was designed to dissipate energy generated by water flowing over the spillway, not to provide passage for juvenile salmon or other aquatic organisms. The configuration of the stilling basin and the placement of the concrete baffles were designed to dissipate kinetic energy from the water spilling through the spillway to reduce turbulence and shoreline erosion downstream of the dam. Juvenile fish passing through the spillway may be driven against the concrete baffles as the water loses energy. Passage conditions may improve with the installation of the deflectors. The deflectors should produce a skimming flow along the surface of the water. This skimming flow may be sufficient to carry the juvenile salmon across the top of the concrete baffles at the downstream edge of the stilling basin. However, the flow may still force the fish into the rolling water between the baffles and the endsill wall, battering the fish against the concrete.

## 8.02. ENVIRONMENTAL COMPLIANCE.

### a. National Environmental Policy Act.

The U.S. Army Corps of Engineers, Walla Walla District (CENPW) has prepared an Environmental Assessment (EA) for this project. A copy of the EA is in appendix D. The EA is being distributed for public and agency review. Once the review period is complete, CENPW will determine if a Finding of No Significant Impact is appropriate or if an Environmental Impact Statement is needed.

b. Clean Water Act.

Placement of temporary bulkheads and construction of the spillway deflectors and training wall extension will be subject to the requirements of the Clean Water Act. Placement of temporary bulkheads is covered under nationwide permit number 33, Temporary Construction, Access and Dewatering. Construction of the deflectors and training wall extension is covered under nationwide permit number 25, Structural Discharge, as the concrete and grout for these structures will be placed in tightly sealed cells. The Corps will not need to prepare a Section 404(b)(1) evaluation. Construction of the training wall extension(s) is subject to section 10 requirements but, because the training wall extension(s) would be located in an area closed to boat traffic, there would be no impacts on navigation. The contractor will be required to obtain a water quality standards modification from Washington Department of Ecology for the discharge of the pulverized concrete from the anchor drilling. The contractor will be required to obtain a Hydraulic Project Approval from the Washington Department of Fish and Wildlife prior to installing the deflectors and training wall extension(s).

c. Fish and Wildlife Coordination Act.

Under this act, Federal agencies proposing water resource development projects are required to coordinate with the U.S. Fish and Wildlife Service (USFWS) for evaluation of effects the project may have on fish and wildlife resources. The Corps has coordinated with the USFWS (telephone conversation on 13 December 1995, between Lonnie Mettler of CENPW and Dan Haley of USFWS) and discussed the deflector project. The Corps and USFWS agreed there would be no need for a Coordination Act Report or a Planning Aid Letter as long as there was no change in the alternatives as described in this EA.

d. Endangered Species Act (ESA).

(1) Bald Eagles and Peregrine Falcon.

Federal agencies are required to consult with USFWS for actions they intend to implement that may jeopardize the existence of listed species. The Corps has identified two species, the wintering bald eagle and the migrating peregrine falcon, which may utilize the habitat in the project area. No impacts to individuals of these listed species are anticipated by the construction and operation of the spillway deflectors and training wall extension(s). The proposed work site is already disturbed and is a center of human activities. Any eagles or falcons in the vicinity of the project would be passing through and would easily avoid the construction site. The construction and operation of the deflectors would not adversely affect food sources for either of the species. Based primarily on the fact that wintering bald eagles and migrating peregrine falcons will not be present during the construction window (August - March) and that food sources or habitats of these two species will not be affected, the Corps has made a "No Effect" determination.

(2) Endangered Salmon Stocks.

Three species of salmon pass over Ice Harbor Dam: Spring/summer chinook, fall chinook, and sockeye salmon. The two chinook species are listed as threatened species under Endangered Species Act (ESA), while the sockeye salmon is listed as endangered. Ice Harbor Dam is the first Snake River dam encountered by adult salmon migrating upstream to spawn and the last dam encountered by outmigrating juvenile salmon before they enter the Columbia River. The Corps has written a coordination letter to National Marine Fisheries Service (NMFS) stating that the construction of the spillway deflectors is not likely to adversely affect these listed species. A copy of this letter is in appendix D. The Corps proposes installing the spillway deflectors as per the March 2, 1995, National Marine Fisheries Biological Opinion, *Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years*, prepared by NMFS.

e. Cultural Resources.

Coordination for cultural and historical properties must be in compliance with Sections 106 and 110 of the National Historic Preservation Act (NHPA). All construction activities for the spillway deflectors would take place at a completed Corps project in an area that has been previously disturbed. Since the project constitutes a modification to an existing non-eligible structure, the Corps has determined there would be "no effect to cultural or historical properties" and has forwarded this determination to the Washington State Historic Preservation Office (SHPO). The SHPO has concurred with this determination. Compliance with the NHPA is complete.

## SECTION 9.0 - COSTS AND SCHEDULE

The estimated construction cost of installing deflectors on the center 8 spill bays is \$6.8 million. Appendix E contains the summary of the estimated construction costs. Several construction dewatering schemes were identified by a value engineering study, which could save up to \$1.8 million. The contract documents are being written to allow the contractor to choose and design their own dewatering system. The contract is scheduled to be awarded by 15 July 1996 with a completion date of 15 March 1997. A construction schedule is presented in figure 9-1, on the following page.

The estimated cost of preparing the letter supplement addressing improvements for adult fish passage (including additional model testing) is \$300,000. The letter supplement is scheduled to be completed by the fall of 1996.

Starting Date is 6/21/96

## Ice Harbor 8 Spillway Deflectors Summary Schedule

Finish Date is 3/10/97

ID	Task Name	Duration	Start	Finish	Predecessors	6						Qtr 3, 1996			Qtr 4, 1996			Qtr 1, 1997			Qtr 2, 1997			Q	
						Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul						
1	SPILLWAY DEFLECTOR INSTALLATION	203.82d	7/16/96	3/10/97																					
2	MOBILIZATION	39.05d	7/16/96	8/28/96																					
7	DEMO OF FOR BULKHEAD SUPPORT	1.18d	8/28/96	8/29/96																					
10	REBAR DOWEL INSTALLATION	12.55d	8/28/96	9/11/96																					
19	I-BULKHEAD - STAGE 1	7.12d	9/3/96	9/10/96																					
27	SAW CUT CONCRETE - STAGE 1	4.44d	9/10/96	9/16/96																					
30	CONCRETE - STAGE 1	30.72d	9/16/96	10/19/96																					
38	DEMO SPILLWAY - STAGE 1	1.9d	10/19/96	10/22/96																					
41	SHOTCRETE - STAGE 1	3.73d	10/21/96	10/25/96																					
48	R-BULKHEAD - STAGE 1	7.19d	10/25/96	11/2/96																					
55	I-BULKHEAD - STAGE 2	7.12d	10/29/96	11/6/96																					
63	SAW CUT CONCRETE - STAGE 2	4.44d	11/6/96	11/11/96																					
66	CONCRETE - STAGE 2	30.72d	11/11/96	12/16/96																					
74	DEMO CONCRETE - STAGE 2	1.9d	12/16/96	12/18/96																					
77	SHOTCRETE - STAGE 2	6.47d	12/18/96	1/2/97																					
84	R-BULKHEAD - STAGE 2	7.19d	1/2/97	1/10/97																					
91	I-BULKHEAD - STAGE 3	6.73d	1/6/97	1/14/97																					
98	SAW CUT REMOVAL - STAGE 3	4.44d	1/14/97	1/18/97																					
101	CONCRETE - STAGE 3	27.78d	1/18/97	2/19/97																					
108	DEMO CONCRETE - STAGE 3	2.42d	2/19/97	2/21/97																					
112	SHOTCRETE - STAGE 3	3.2d	2/20/97	2/24/97																					
119	R-BULKHEAD - STAGE 3	9.61d	2/24/97	3/6/97																					
126	RETROFIT FLOATING BULKHEAD	4.84d	2/24/97	3/1/97																					
130	DEMOLITION	2.61d	3/6/97	3/10/97																					
132	PROJECT COMPLETE	0d	3/10/97	3/10/97	111,129,131																				3/10

(Figure 9-1)

## SECTION 10.0 - SUMMARY AND RECOMMENDATIONS

Low, current and projected future fish estimates for Snake River listed stocks emphasize the need to proceed rapidly with any measures that can immediately improve fish passage conditions on the Snake River. Anticipated operations on the Snake River will likely include some level of spill to reach fish passage efficiency (FPE) goals at U.S. Army Corps of Engineers projects. The total dissolved gas (TDG) problem could seriously limit the ability to reach these goals. During spill operations, Ice Harbor produces the highest TDG levels in the system.

Spillway deflectors will provide an estimated 5- to 10-percent improvement in TDG levels for fish spill and will improve the likelihood of meeting FPE goals. Model studies have indicated that deflector installation should not adversely affect existing adult fish passage rates at Ice Harbor Dam. In addition, improvements to the deflector design, such as the 15-foot-radius transition and deflector pier blocks, should reduce the risk that deflectors will increase mechanical injury or mortality to juvenile fish during spill. This may reduce concerns raised in juvenile fish data sets suggesting a measurable (but not statistically significant) mortality associated with deflector passage.

Considerable uncertainty exists with other larger-scale TDG improvement measures. Significant time and effort will be necessary to determine if these measures do provide a significant level of improvement without causing other adverse conditions.

Installation of deflectors on the center 8 of the existing 10 spill bays at Ice Harbor Dam is recommended as an interim solution to reduce the production of TDG. The construction cost for the 8 deflectors has been estimated at \$6.8 million. Contract documents for installation of the eight deflectors are currently being prepared with an anticipated contract award date of 16 July 1996. The construction period will extend from August 1996 through March 1997.

Based on model tests, spillway discharges with deflectors will create undesirable eddy currents in the vicinity of adult fishway entrances; however, these are judged to be acceptable for the short term. Results from the 1:55 scale Ice Harbor Dam's general model indicates that the addition of training wall extensions, between spill bays 1 and 2 and spill bays 9 and 10, improve hydraulic conditions for adult fish passage. Additionally, relocation and realignment of the north shore fishway entrance in conjunction with the training wall extension may provide additional benefits. The design of the training wall extensions (length and height) and potential relocation/realignment of the north spillway fishway entrance will be modeled and addressed in a letter supplement to this design memorandum.

Preliminary model investigations at Waterways Experiment Station indicate that installation of deflectors at Ice Harbor will result in higher cross channel velocities

and greater surface turbulence near the end of the downstream navigation lock guidewall. These conditions are likely to make it difficult for barge traffic to navigate into and out of the lock. Further investigations of these conditions and possible ways to reduce adverse effects on navigation will also be addressed in the letter supplement to this design memorandum.

The anticipated engineering costs (including additional model testing) for preparing the letter supplement is estimated at \$300,000. The design and construction for the additional modifications will be presented in the letter supplement. The anticipated schedule for the letter supplement, procurement and supply, contract advertisement/award, and construction is shown below:

ITEM	START	END
Letter Supplement	16 April 1996	31 October 1996
Plans and Specifications	1 November 1996	30 April 1997
Advertise and Award	1 May 1997	16 July 1997
Construction	1 August 1997	31 March 1998

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## TABLES

# Ice Harbor Standard Spill Pattern for Adult Fish Passage

1	2	3	4	SPILLBAY						8	9	10	TOTAL STOPS	TOTAL SPILL (kcfs)
1													1	1.7
1	1										1	1.5	4.5	7.7
1	1	1						1	1	1.5			6.5	11.1
1	2	1						1	2	1.5			8.5	14.5
1	2	1	1				1	1	2	1.5			10.5	17.9
1	2	1	1	1	1	1	1	2	2	1.5			12.5	21.3
1	2	2	1	1	1	1	2	2	2	1.5			14.5	24.7
1	2	2	2	1	1	2	2	2	2	1.5			16.5	28.1
1	2	2	2	2	2	2	2	2	2	1.5			18.5	31.5
1	2	2	2	3	3	2	2	2	2	1.5			20.5	34.9
1	2	2	3	3	3	3	2	2	2	1.5			22.5	38.3
1	2	3	3	3	3	3	3	2	2	1.5			24.5	41.7
1	2	3	3	4	4	3	3	2	2	1.5			26.5	45.1
1	2	3	3	4	4	4	3	2	2	1.5			27.5	46.8
1	2	3	3	5	5	4	3	2	2	1.5			29.5	50.2
1	2	3	4	5	5	4	3	3	3	1.5			31.5	53.6
1	3	3	5	5	5	4	3	3	3	1.5			33.5	57.0
1	3	4	5	6	5	4	3	3	3	1.5			35.5	60.4
2	3	4	6	6	5	4	4	3	3	1.5			38.5	65.5
2	3	4	6	6	6	5	4	3	3	1.5			40.5	68.9
2	3	5	6	6	6	5	4	3	3	1.5			41.5	70.6
2	3	5	6	7	6	5	5	3	3	1.5			43.5	74.0
2	3	5	7	7	6	6	5	3	3	1.5			45.5	77.4
2	3	6	7	8	6	6	5	3	3	1.5			47.5	80.8
2	4	6	7	8	6	6	5	3	3	1.5			48.5	82.5
2	4	6	7	8	7	7	5	4	2			52	88.4	
2	4	6	8	8	7	7	6	4	2			54	91.8	
2	4	6	8	9	8	7	6	4	2			56	95.2	
2	4	7	8	9	9	7	6	4	2			58	98.6	
2	4	7	9	10	9	7	6	4	2			60	102.0	
2	4	7	10	10	9	8	6	4	2			62	105.4	
2	4	7	10	11	9	8	7	4	2			64	108.8	
2	4	7	11	11	10	8	7	4	2			66	113.9	
2	4	8	11	12	10	8	7	4	2			68	115.6	
2	4	8	11	13	10	9	7	4	2			70	119.0	

Table 1

# Ice Harbor Alternate Spill Test Pattern for Minimizing Total Dissolved Gas

1	2	3	4	SPILLBAY						8	9	10	TOTAL STOPS	TOTAL SPILL (kcfs)
1													1	1.7
1	1										1	1.5	4.5	7.7
1	1	1						1	1	1.5			6.5	11.1
1	2	1						1	2	1.5			8.5	14.5
1	2	1	1				1	1	2	1.5			10.5	17.9
1	2	1	1	1	1	1	1	2	2	1.5			12.5	21.3
1	2	2	1	1	1	1	2	2	2	1.5			14.5	24.7
1	2	2	2	1	1	2	2	2	2	1.5			16.5	28.1
1	2	2	2	2	2	2	2	2	2	1.5			18.5	31.5
1	1	1	2	8	2	1	1	2	2	1.5			20.5	34.9
1	2	1	2	8	2	1	2	2	2	1.5			22.5	38.3
1	2	2	2	8	2	2	2	2	2	1.5			24.5	41.7
1	1	1	1	9	9	1	1	1	1	1.5			26.5	45.1
1	1	2	2	8	8	2	1	1	1	1.5			27.5	46.8
1	1	1	2	9	9	2	2	1	1	1.5			29.5	50.2
1	2	2	2	9	9	2	2	1	1	1.5			31.5	53.6
1	0	1	9	9	9	1	1	1	1	1.5			33.5	57.0
1	1	1	9	9	9	2	1	1	1	1.5			35.5	60.4
1	0	2	10	10	10	2	1	1	1	1.5			38.5	65.5
1	2	2	10	10	10	2	1	1	1	1.5			40.5	68.9
1	2	2	10	11	10	2	1	1	1	1.5			41.5	70.6
1	1	2	11	11	11	2	2	1	1	1.5			43.5	74.0
1	1	2	12	12	12	2	1	1	1	1.5			45.5	77.4
1	2	2	12	12	12	2	2	1	1	1.5			47.5	80.8
1	1	2	9	12	12	9	2	1	1	1.5			50.5	85.9
1	1	2	10	12	12	9	2	1	2				52	88.4
1	1	2	11	12	12	10	2	1	2				54	91.8
1	1	2	11	12	12	11	2	2	2				56	95.2
1	1	2	12	12	12	12	2	2	2				58	98.6
2	2	2	12	12	12	12	2	2	2				60	102.0
1	2	9	12	12	12	9	2	1	2				62	105.4
1	2	10	12	12	12	10	2	1	2				64	108.8
1	2	11	12	12	12	11	2	2	2				67	113.9
2	2	11	12	12	12	11	2	2	2				68	115.6
2	2	12	12	12	12	12	2	2	2				70	119.0

Table 2

# Ice Harbor 1:55 Scale General Model Spillbay Deflector Test Conditions

Flow Distribution (Kcfs)		Power House Unit Discharge (Kcfs)						Tail Water Elev.		Spillway Gate Stop - Openings in Feet										Total Stops
Spillway	PH	Total River	1	2	3	4	5	6		1	2	3	4	5	6	7	8	9	10	
Base Line Conditions; No Spillway Deflectors																				
25	50	75	16.7	16.7	16.7	16.7	0.0	0.0	0.0	344.5	1	2	2	1	1	1	2	2	1.5	14.5
25	100	125	16.7	16.7	16.7	16.7	16.7	16.7	16.7	348.0										
45	50	95	16.7	16.7	16.7	16.7	0.0	0.0	0.0	346.0	1	2	3	3	4	3	3	2	1.5	26.5
45	100	145	16.7	16.7	16.7	16.7	16.7	16.7	16.7	350.0										
60	50	110	16.7	16.7	16.7	16.7	0.0	0.0	0.0	347.0	1	3	4	5	6	4	3	3	1.5	35.5
60	100	160	16.7	16.7	16.7	16.7	16.7	16.7	16.7	351.0										
Six Spill Deflectors; Bays 3 Through 8																				
25	30	55	12.3	0.0	0.0	17.7	0.0	0.0	0.0	342.7	1.2	2	1.2	1.2	1.2	1.4	1.4	2.5	1	14.5
25	60	85	12.3	12.3	0.0	17.7	0.0	17.7	17.7	345.2	1.2	2	1.2	1.4	1.4	1.4	1.4	2	1.3	14.5
25	90	115	12.3	12.3	12.3	17.7	17.7	17.7	17.7	347.0	1.2	2	1.2	1.4	1.4	1.4	1.4	2	1.3	14.5
45	60	105	12.3	12.3	0.0	17.7	0.0	17.7	17.7	346.7	2	4	2	2	3	3	2	5	1.5	26.5
45	90	135	12.3	12.3	12.3	17.7	17.7	17.7	17.7	348.5	2	4	2	2	3	3	2	4	2.5	26.5
60	90	150	12.3	12.3	12.3	17.7	17.7	17.7	17.7	351.0	2.5	5.5	3	3	3.5	3.5	3	5	3	35.5
Eight Spill Deflectors; Bays 2 Through 9 (with and without training wall extensions)																				
25	30	55	12.3	0.0	0.0	17.7	0.0	0.0	0.0	342.7	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	14.5
25	60	85	12.3	12.3	0.0	17.7	0.0	17.7	17.7	345.2										14.5
25	90	115	12.3	12.3	12.3	17.7	17.7	17.7	17.7	347.0										14.5
45	60	105	12.3	12.3	0.0	17.7	0.0	17.7	17.7	346.7	2	3	3	3	3	3	3	2	1.5	26.5
45	90	135	12.3	12.3	12.3	17.7	17.7	17.7	17.7	348.5										26.5
60	90	150	12.3	12.3	12.3	17.7	17.7	17.7	17.7	351.0	2	4	4	4	4	4	4	4	1.5	35.5

Note:

1. The North spillway entrance, North powerhouse entrance and the South powerhouse entrance were each set to discharge 700 cfs.
2. Tailwater elevations were measured 2200 feet downstream of the spillway crest.

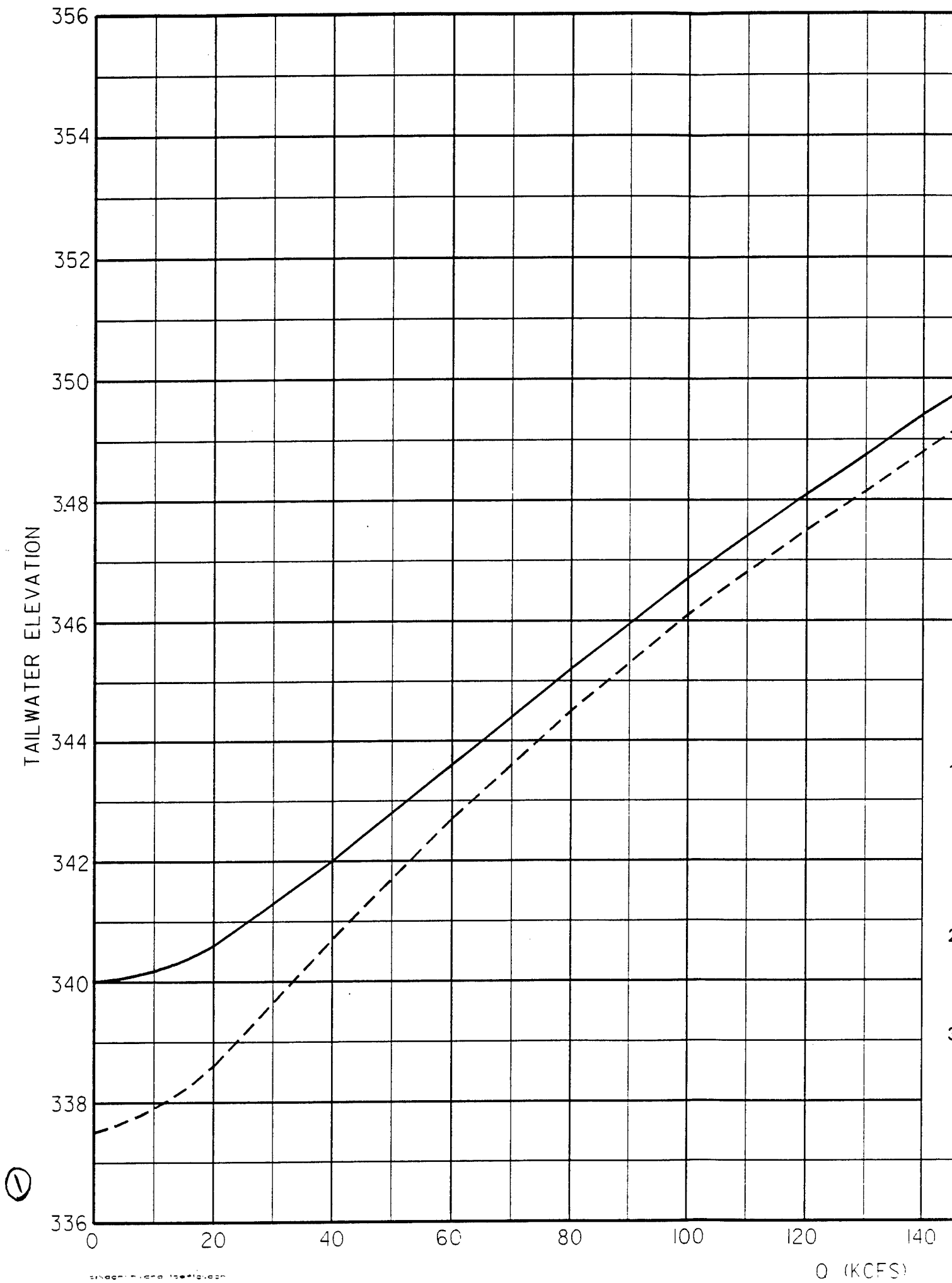
Table 3

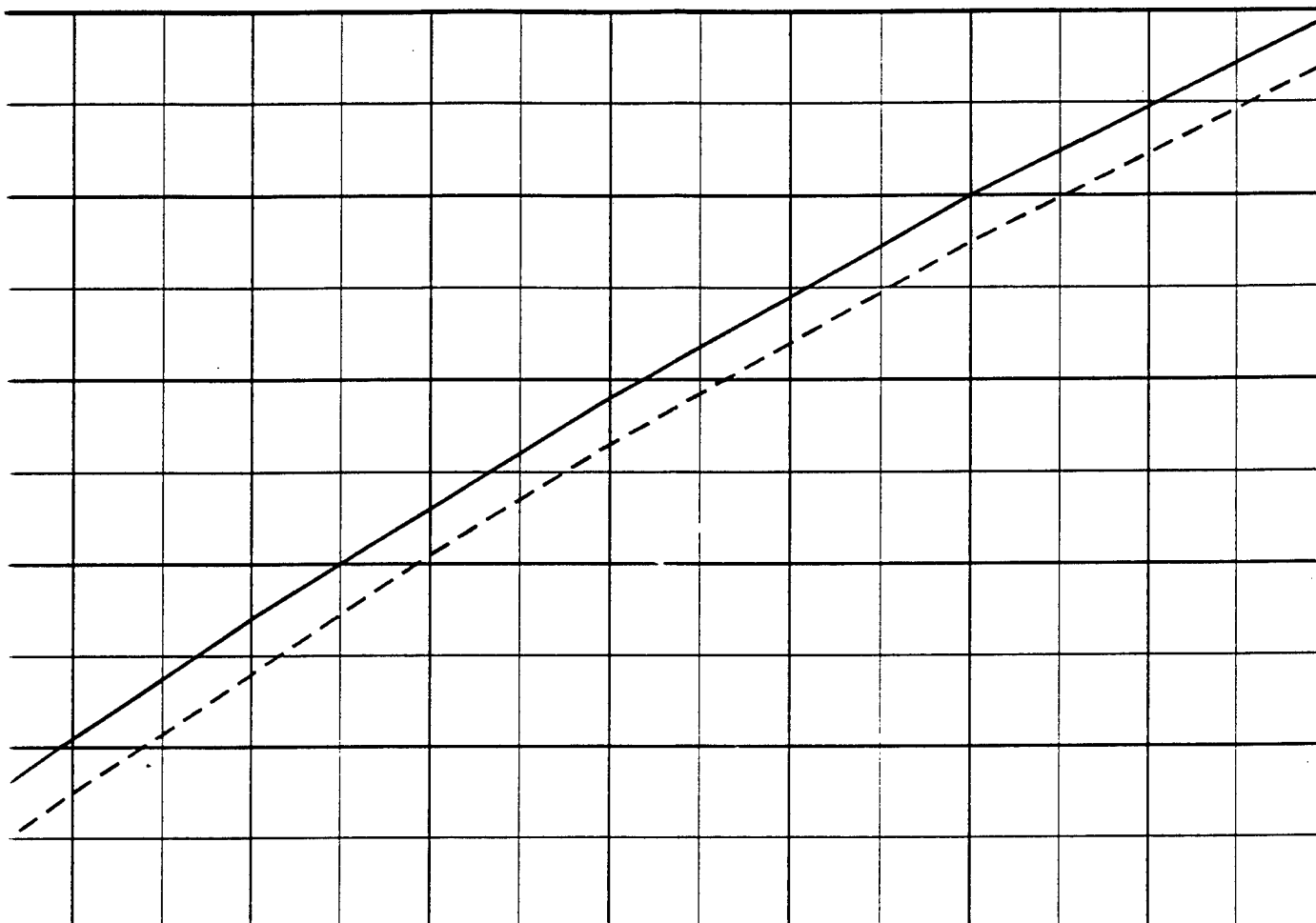
**Ice Harbor Spill Pattern  
(Deflectors in Bays 2 through 9)**

1	SPILLBAY									TOTAL STOPS	TOTAL SPILL (kcfs)
	2	3	4	5	6	7	8	9	10		
1										1	1.7
1	1							1	1.5	4.5	7.7
1	1	1					1	1	1.5	6.5	11.1
1	1	1	1			1	1	1	1.5	8.5	14.5
1	1	1	1	1	1	1	1	1	1.5	10.5	17.9
1	1.5	1.5	1.5	1.5	1	1	1	1	1.5	12.5	21.3
1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	14.5	24.7
1	2	2	2	2	1.5	1.5	1.5	1.5	1.5	16.5	28.1
1	2	2	2	2	2	2	2	2	1.5	18.5	31.5
1	2.5	2.5	2.5	2.5	2	2	2	2	1.5	20.5	34.9
1	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.5	22.5	38.3
2	3	3	2.5	2.5	2.5	2.5	2.5	2.5	1.5	24.5	41.7
2	3	3	3	3	3	3	3	2	1.5	26.5	45.1
2	3.5	3.5	3	3	3	3	3	3	1.5	28.5	48.5
2	3.5	3.5	3.5	3.5	3.5	3.5	3	3	1.5	30.5	51.9
2	4	4	3.5	3.5	3.5	3.5	3.5	3.5	1.5	32.5	55.3
2	4	4	4	4	4	4	3.5	3.5	1.5	34.5	58.7
2	4.5	4.5	4	4	4	4	4	4	1.5	36.5	62.1
2	4.5	4.5	4.5	4.5	4.5	4.5	4	4	1.5	38.5	65.5
2	5	5	4.5	4.5	4.5	4.5	4.5	4.5	1.5	40.5	68.9
2	5	5	5	5	5	5	4.5	4.5	1.5	42.5	72.3
2	5.5	5.5	5	5	5	5	5	5	1.5	44.5	75.7
2	5.5	5.5	5.5	5.5	5.5	5.5	5	5	1.5	46.5	79.1
2	6	6	5.5	5.5	5.5	5.5	5.5	5.5	1.5	48.5	82.5
2	6	6	6	6	6	6	5.5	5.5	1.5	50.5	85.9
2	6	6	6	6	6	6	6	6	2	52	88.4
2	7	7	6	6	6	6	6	6	2	54	91.8
2	7	7	7	7	6	6	6	6	2	56	95.2
2	7	7	7	7	7	7	6	6	2	58	98.6
2	7	7	7	7	7	7	7	7	2	60	102.0
2	8	8	7	7	7	7	7	7	2	62	105.4
2	8	8	8	8	7	7	7	7	2	64	108.8
2	8	8	8	8	8	8	7	7	2	66	112.2
2	8	8	8	8	8	8	8	8	2	68	115.6
2	9	9	8	8	8	8	8	8	2	70	119.0

**Table 4**

## FIGURES





————— Most Likely Maximum Tailwater Elevation  
 - - - - - Most Likely Minimum Tailwater Elevation

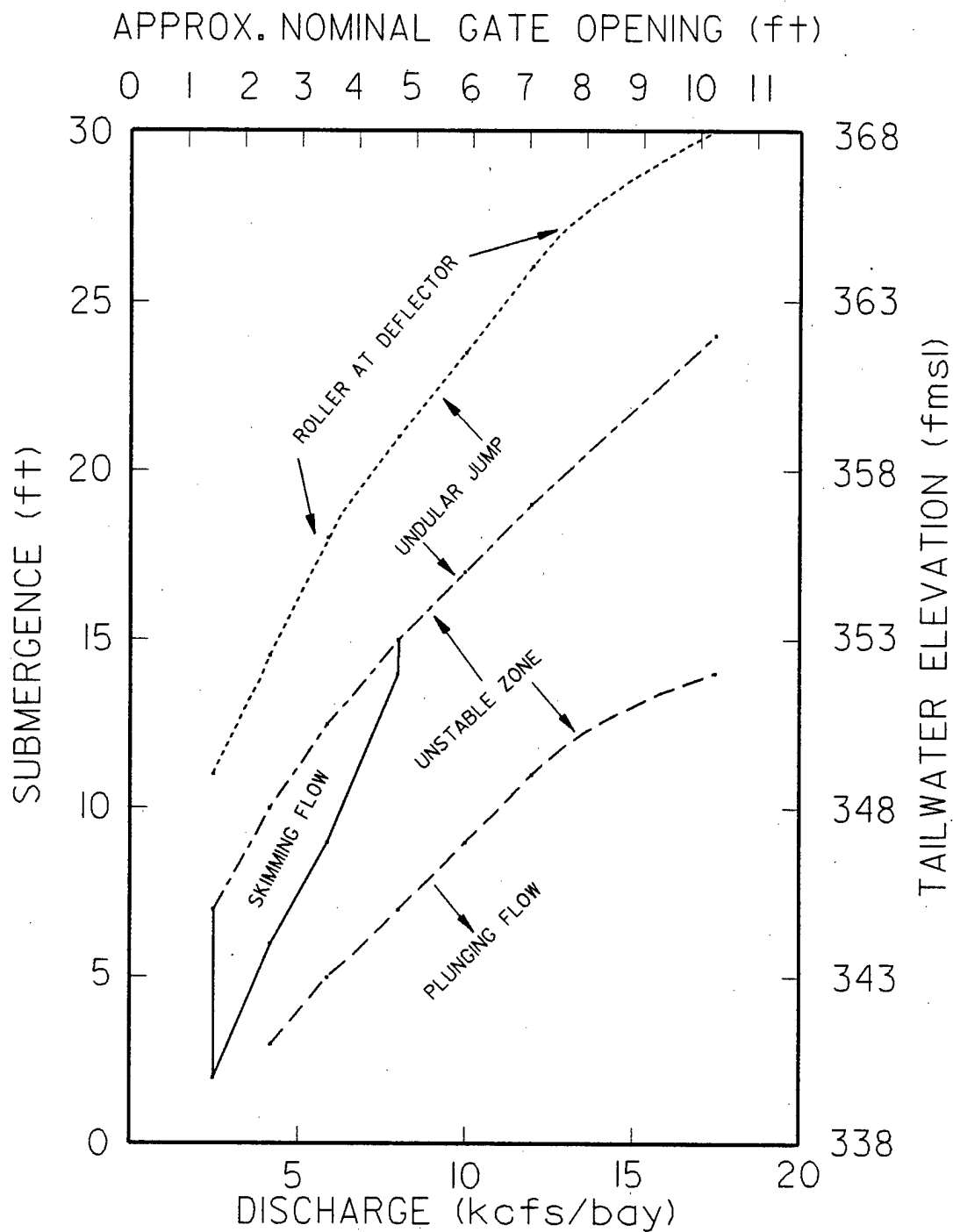
#### NOTES:

1. These two curves, most likely maximum and minimum tailwater elevations, were developed for use in optimizing the elevation of spillway deflectors for the center spill bays at Ice Harbor Dam. These tailwater elevations are for a cross section located approximately 1000 feet downstream from the powerhouse and were derived from HEC-2 backwater curves developed for the Snake and Columbia Rivers by CENPW Hydrology Branch (dated April 1995).
2. A McNary Dam forebay elevation of 340 fmsl and a Columbia River discharge at McNary Dam equal to 3.5 times the Snake River discharge were assumed in obtaining the most likely maximum tailwater elevation curve.
3. A McNary Dam forebay elevation of 337.5 fmsl and a Columbia River discharge at McNary Dam equal to 2.0 times the Snake River discharge were assumed in obtaining the most likely minimum tailwater elevation curve. (However, it should be noted that the full operating range of McNary's forebay is from 335 to 340 fmsl.)

120 140 160 180 200 220 240 260

Q (KCFS)

FIGURE 1

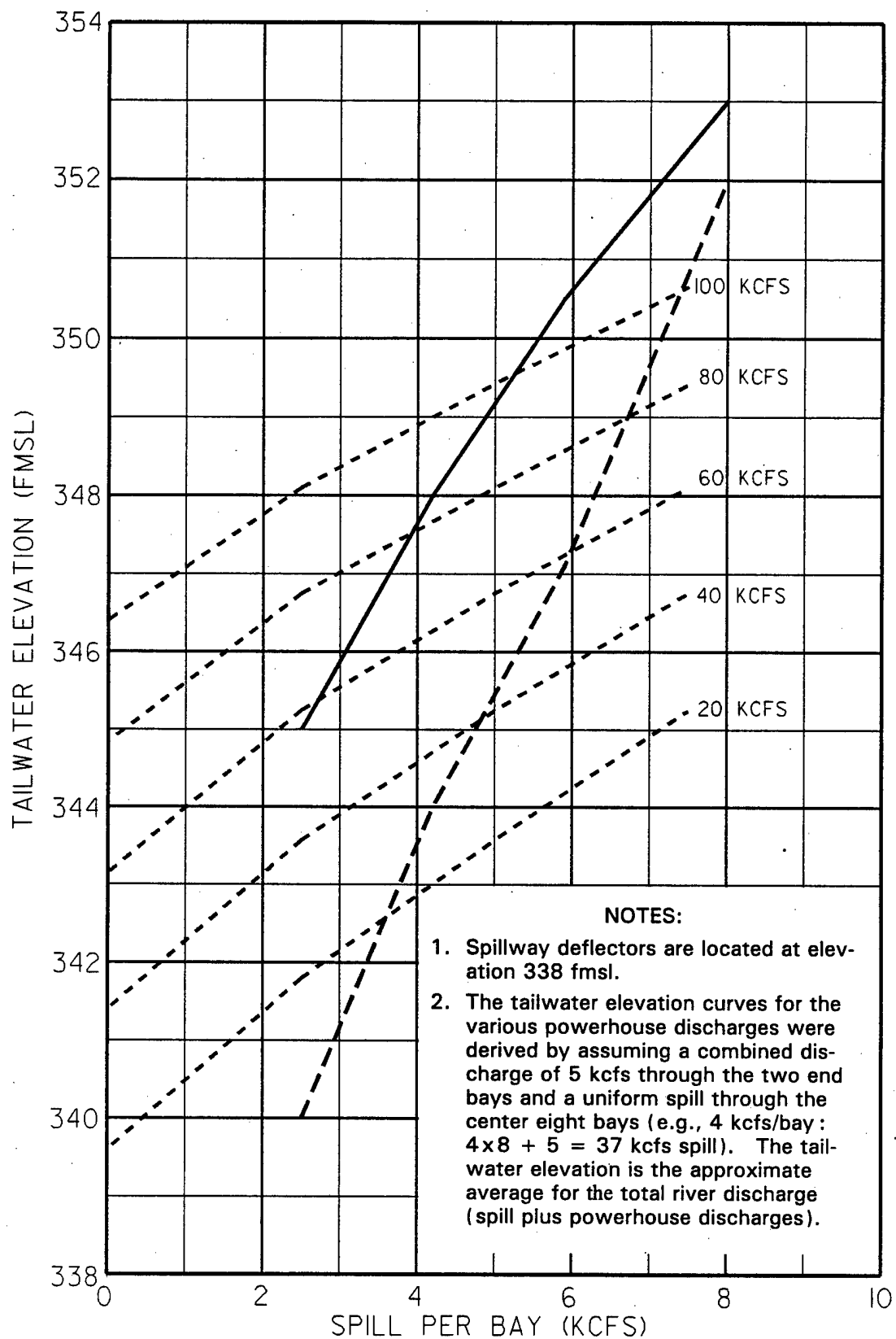


NOTE: The Type 2 deflector has a 12.5-foot horizontal projection from the spillway face and a 15-foot radius fillet between the deflector's horizontal surface and the spillway face.

- ROLLER FORMS AT DEFLECTOR
- - - - - MINIMUM SUBMERGENCE OF UNDULAR JUMP TO FORM
- MIN. SUBMERGENCE SKIMMING FLOW
- - - - - MAX. SUBMERGENCE PLUNGING FLOW

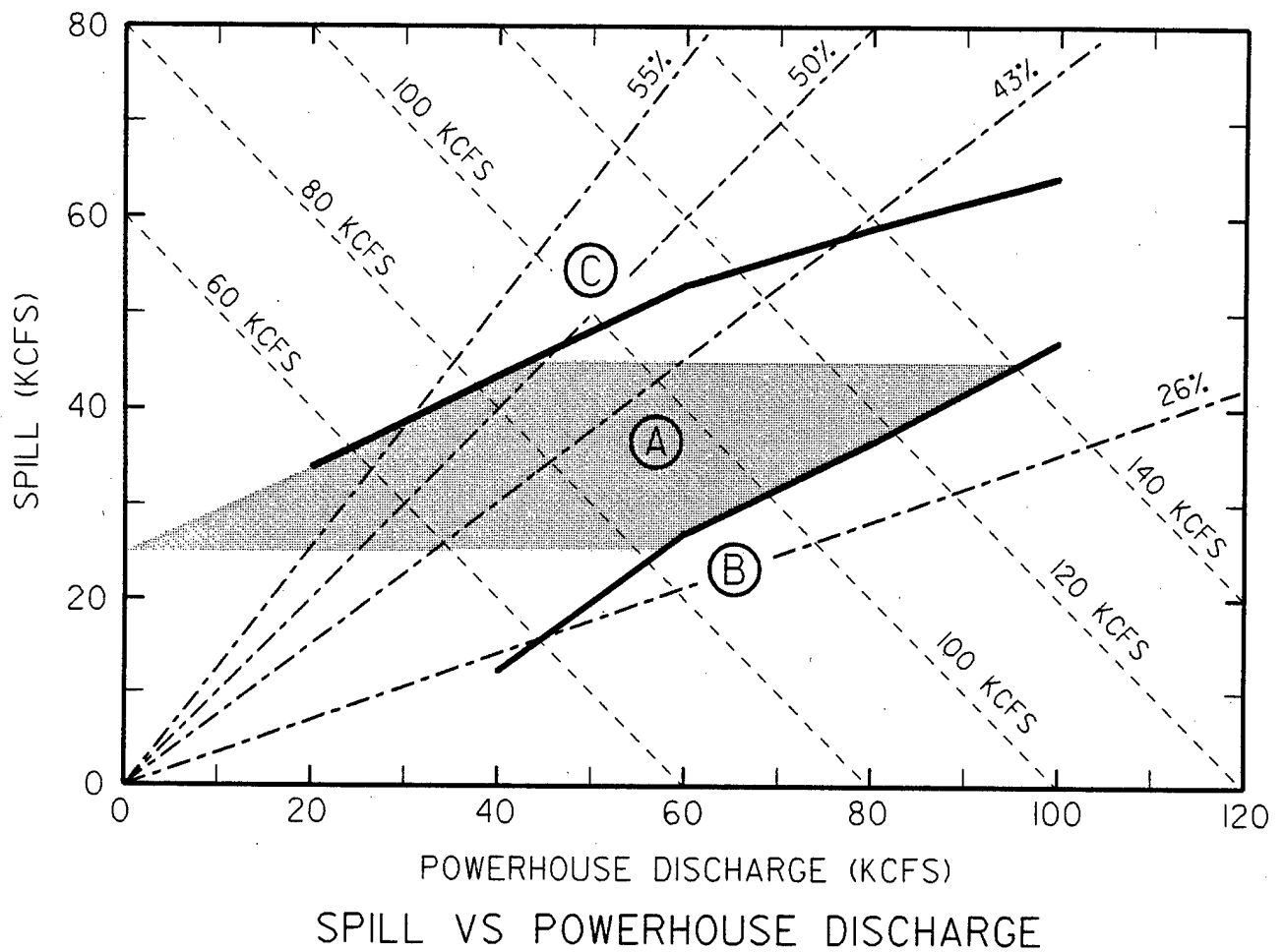
TYPE 2 - FLOW DEFLECTOR  
AT ELEVATION 338

FIGURE 2



——— UPPER LIMIT OF SKIMMING FLOW  
 - - - - - LOWER LIMIT OF SKIMMING FLOW  
 - - - - - TAILWATER ELEVATION CURVES FOR  
 VARIOUS POWERHOUSE DISCHARGES

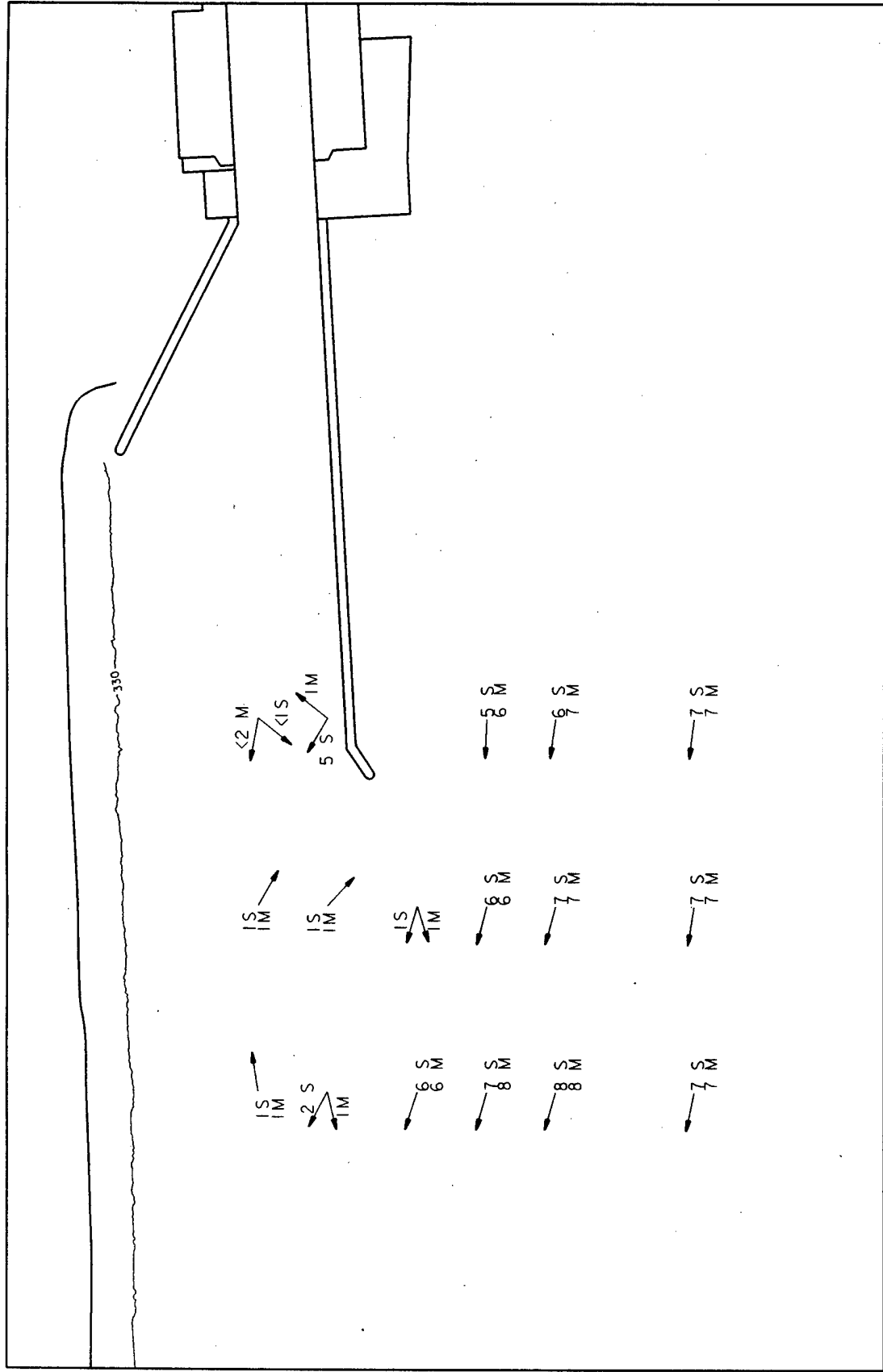
FIGURE 3



SPILL	FGE	FPE
26%	73%	80%
43%	65%	80%
50%	60%	80%
55%	56%	80%

- LEGEND**
- TOTAL RIVER DISCHARGE (KCFS)
  - PERCENT SPILL
  - LIMITS OF SKIMMING FLOW
  - (A) ZONE OF SKIMMING FLOW
  - (B) ZONE OF UNDULAR FLOW
  - (C) ZONE OF MIXED SKIMMING & PLUNGING FLOW

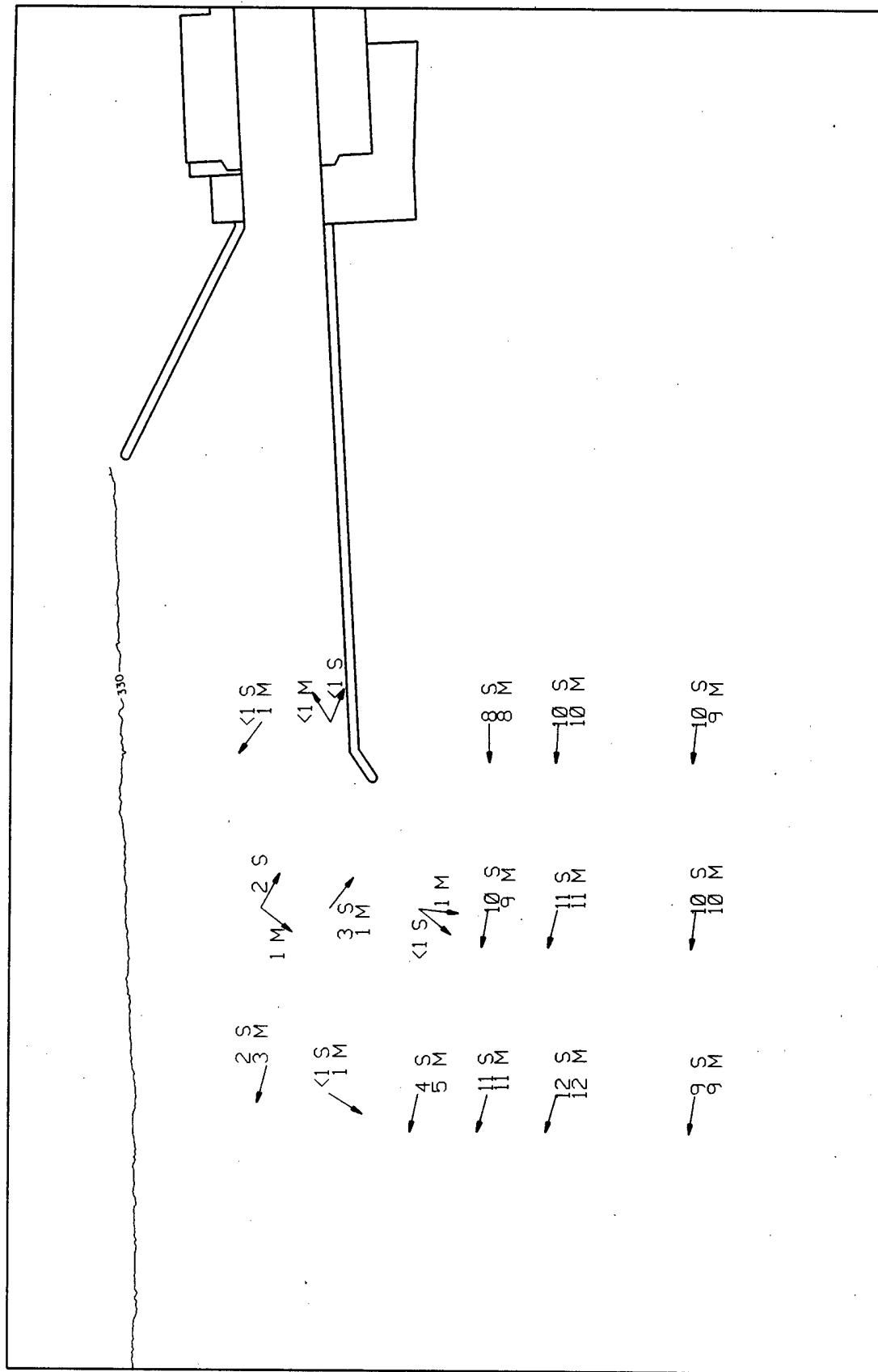
FIGURE 4



**MODEL STUDY**  
**ICE HARBOR GENERAL SPILLWAY**  
**NO DEFLECTOR**  
**NAVIGATION EFFECTS**  
**RIVER DISCHARGE 150,000 CFS**  
**EXPERIMENT 1**

OPERATING CONDITIONS	
NO DEFLECTOR	
POWER HOUSE DISCHARGE	2,550 m <sup>3</sup> /s (90,000 cfs)
SPILLWAY DISCHARGE	1,700 m <sup>3</sup> /s (60,000 cfs)
NONOVERFLOW FISHWAY*	20 m <sup>3</sup> /s (700 cfs)
NORTH FISHWAY*	20 m <sup>3</sup> /s (700 cfs)
TAILWATER EL. 349.7	
*PUMPED FROM TAILWATER	

**FIGURE 7**

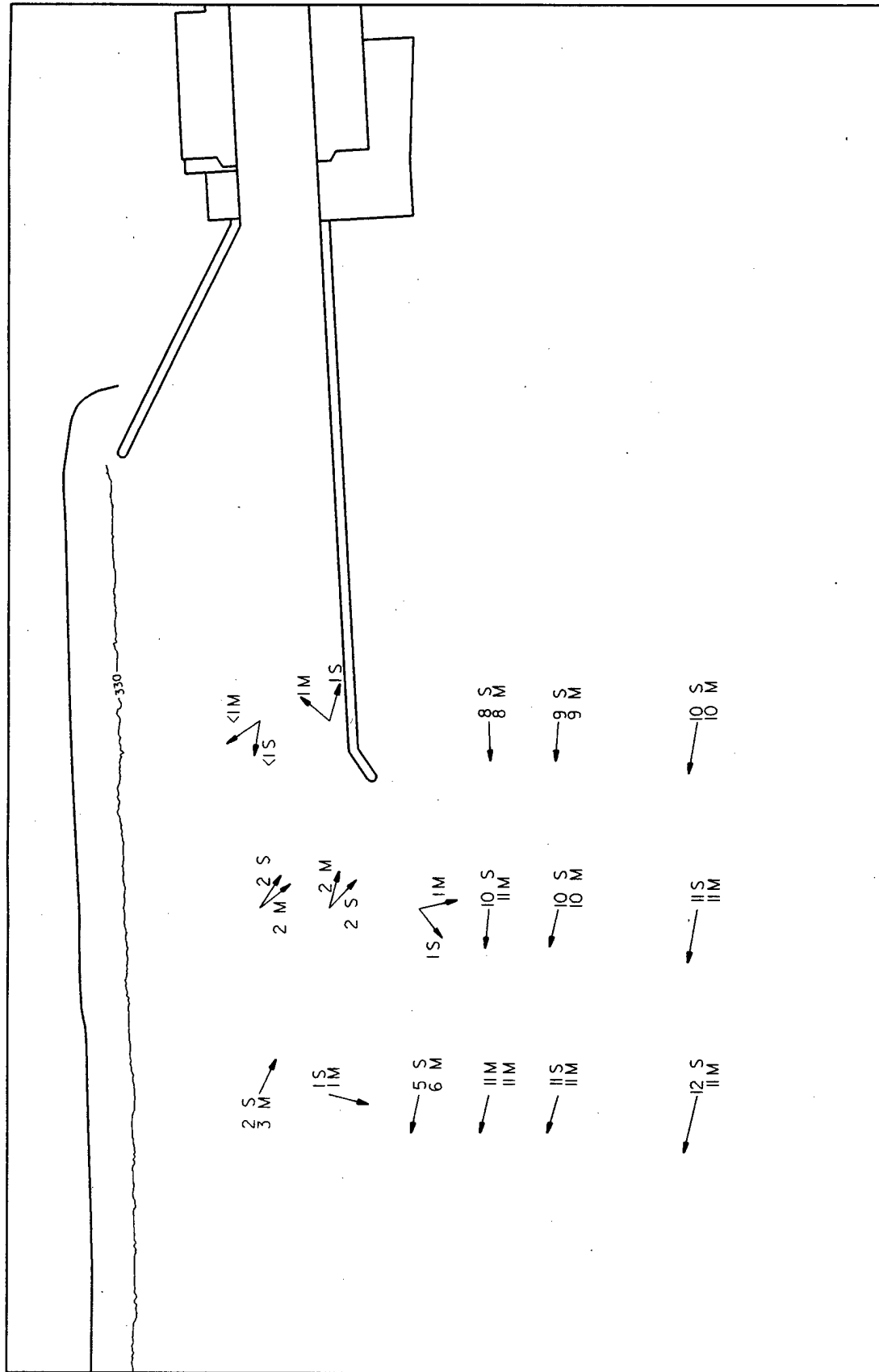


OPERATING CONDITIONS  
EIGHT BAY DEFLECTOR

POWER HOUSE DISCHARGE 2,550 m<sup>3</sup>/s (90,000 cfs)  
 SPILLWAY DISCHARGE 1,700 m<sup>3</sup>/s (60,000 cfs)  
 NONOVERFLOW FISHWAY\* 20 m<sup>3</sup>/s (700 cfs)  
 NORTH FISHWAY\* 20 m<sup>3</sup>/s (700 cfs)  
 TAILWATER EL. 349.7  
 \*PUMPED FROM TAILWATER

MODEL STUDY  
 ICE HARBOR GENERAL SPILLWAY  
 8 BAY DEFLECTOR  
 NAVIGATION EFFECTS  
 RIVER DISCHARGE 150,000 CFS  
 EXPERIMENT 1

FIGURE 8



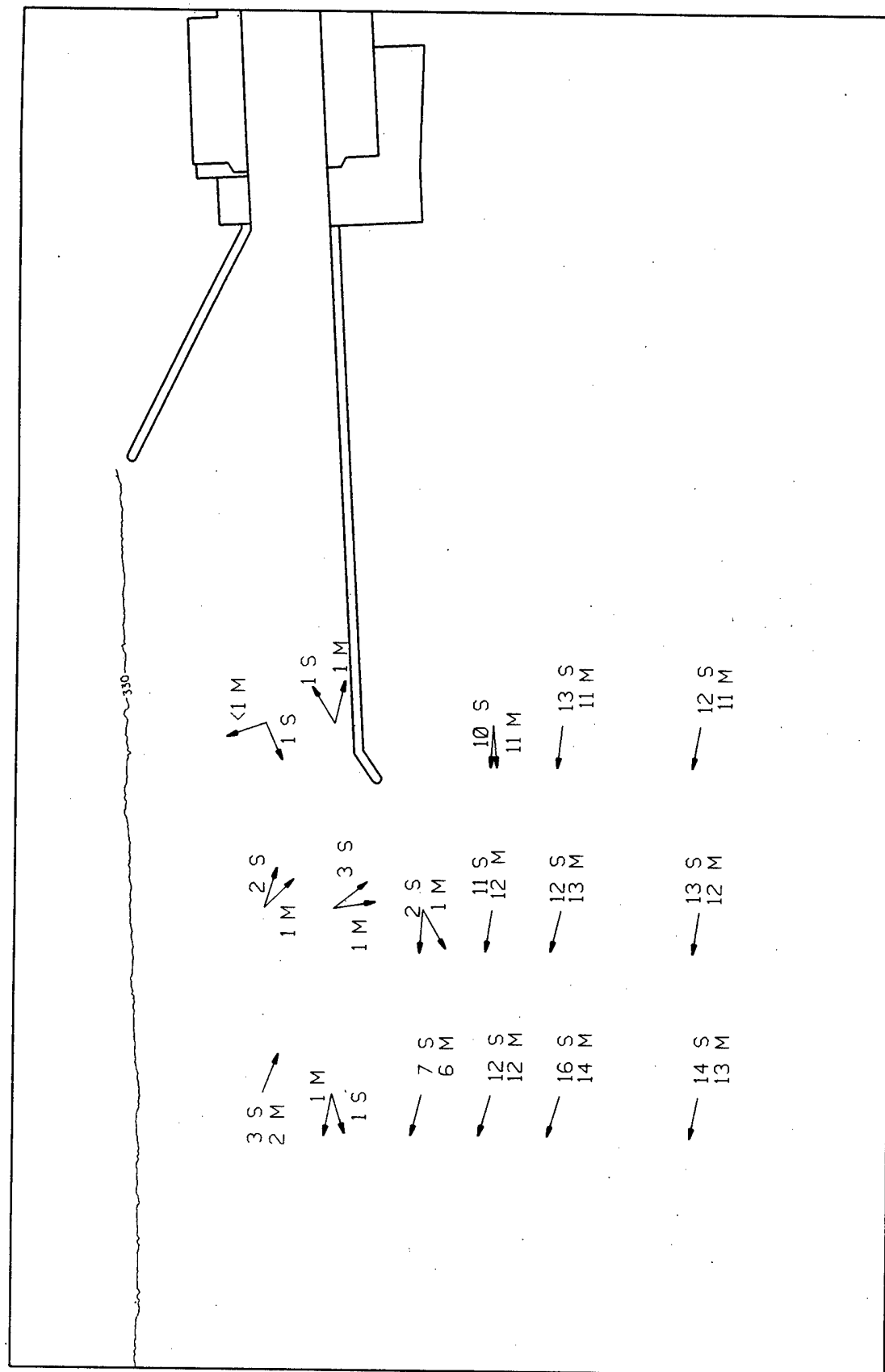
OPERATING CONDITIONS  
NO DEFLECTOR

POWER HOUSE DISCHARGE 2,550 m<sup>3</sup>/s (90,000 cfs)  
 SPILLWAY DISCHARGE 3,820 m<sup>3</sup>/s (135,000 cfs)  
 NONOVERFLOW FISHWAY\* 20 m<sup>3</sup>/s (700 cfs)  
 NORTH FISHWAY\* 20 m<sup>3</sup>/s (700 cfs)

TAIL WATER EL. 354.5  
 \*PUMPED FROM TAILWATER

MODEL STUDY  
 ICE HARBOR GENERAL SPILLWAY  
 NO DEFLECTOR  
 NAVIGATION EFFECTS  
 RIVER DISCHARGE 225,000 CFS  
 EXPERIMENT 2

FIGURE 9



OPERATING CONDITIONS  
EIGHT BAY DEFLECTOR

POWERHOUSE DISCHARGE 2,550 m<sup>3</sup>/s (90,000 cfs)  
 SPILLWAY DISCHARGE 3,820 m<sup>3</sup>/s (135,000 cfs)  
 NONOVERFLOW FISHWAY\* 20 m<sup>3</sup>/s (700 cfs)  
 NORTH FISHWAY 20 m<sup>3</sup>/s (700 cfs)

TAILWATER EL. 354.5  
 \*PUMPED FROM TAILWATER

MODEL STUDY  
 ICE HARBOR GENERAL SPILLWAY  
 8 BAY DEFLECTOR  
 NAVIGATION EFFECTS  
 RIVER DISCHARGE 225,000 CFS  
 EXPERIMENT 2  
 FIGURE 25

# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS

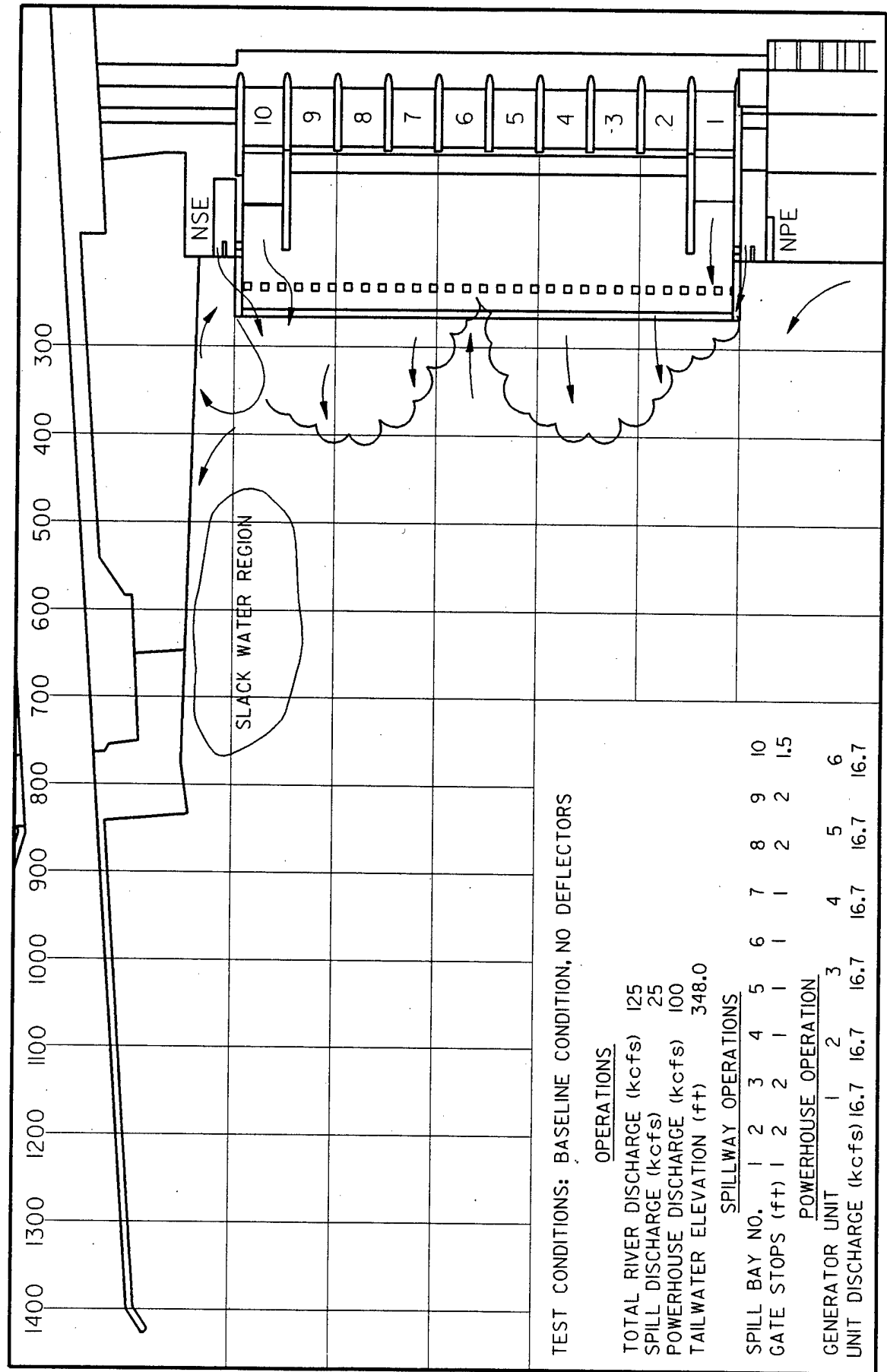


FIGURE 11

**TEST CONDITIONS: BASELINE CONDITION, NO DEFLECTORS**

<u>OPERATIONS</u>						
TOTAL RIVER DISCHARGE (kcfs)	160					
SPILL DISCHARGE (kcfs)	60					
POWERHOUSE DISCHARGE (kcfs)	100					
TAILWATER ELEVATION (ft)	351.0					

<u>SPILLWAY OPERATIONS</u>										
SPILL BAY NO.	1	2	3	4	5	6	7	8	9	10
GATE STOPS (ft)	1	3	4	5	6	5	4	3	3	1.5

<u>POWERHOUSE OPERATION</u>						
GENERATOR UNIT	1	2	3	4	5	6
UNIT DISCHARGE (kcfs)	16.7	16.7	16.7	16.7	16.7	16.7

TEST CONDITIONS: BASELINE CONDITION, NO DEFLECTORS

## OPERATIONS

TOTAL RIVER DISCHARGE (kcfs)	160
SPILL DISCHARGE (kcfs)	60
POWERHOUSE DISCHARGE (kcfs)	100
TAILWATER ELEVATION (ft)	351.0

## SPILLWAY OPERATIONS

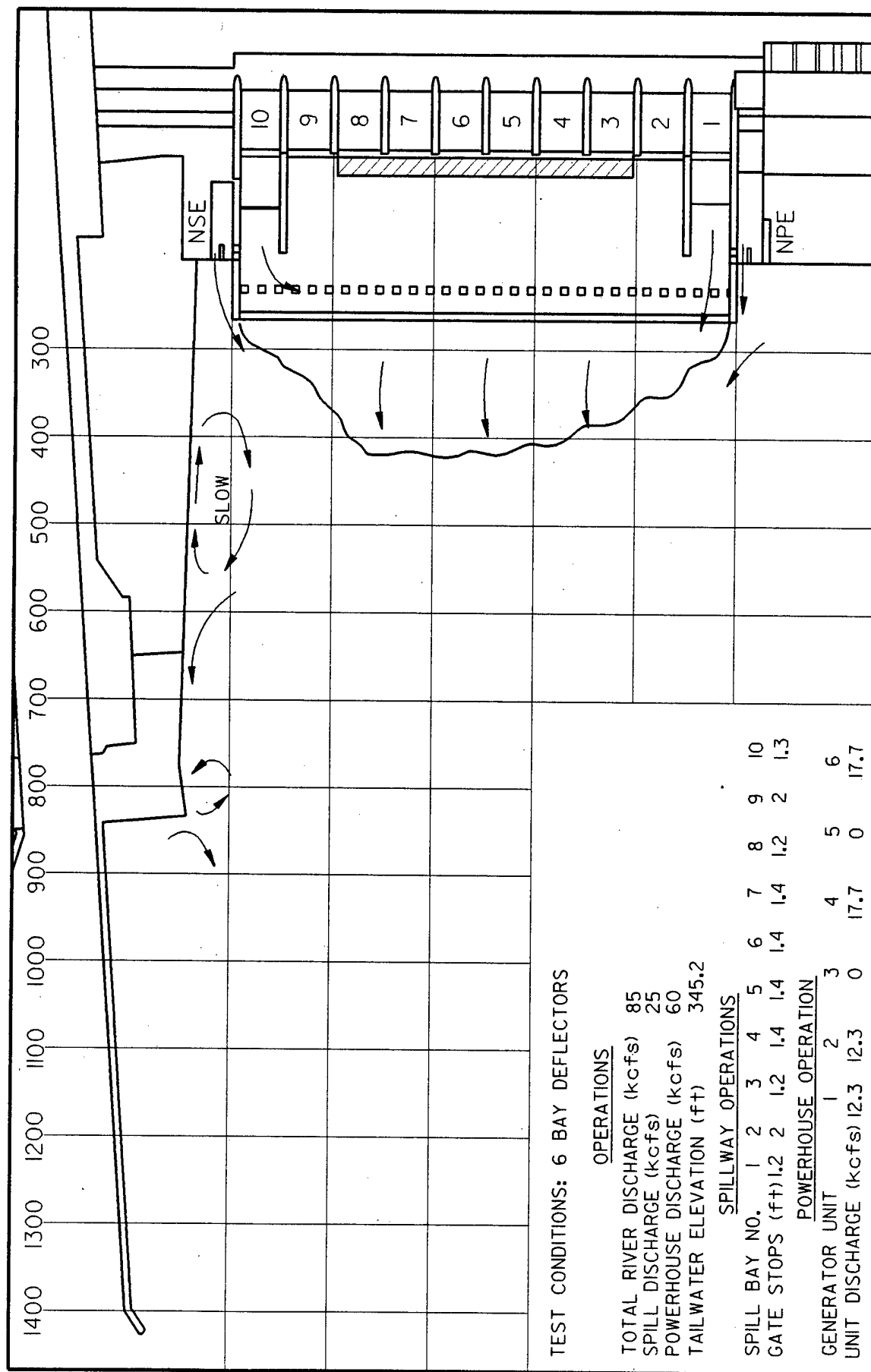
SPILL BAY NO.	1	2	3	4	5	6	7	8	9	10
GATE STOPS (ft)	1	3	4	5	6	5	4	3	3	1.5

## POWERHOUSE OPERATION

GENERATOR UNIT	1	2	3	4	5	6
UNIT DISCHARGE (kcf/s)	16.7	16.7	16.7	16.7	16.7	16.7

FIGURE 12

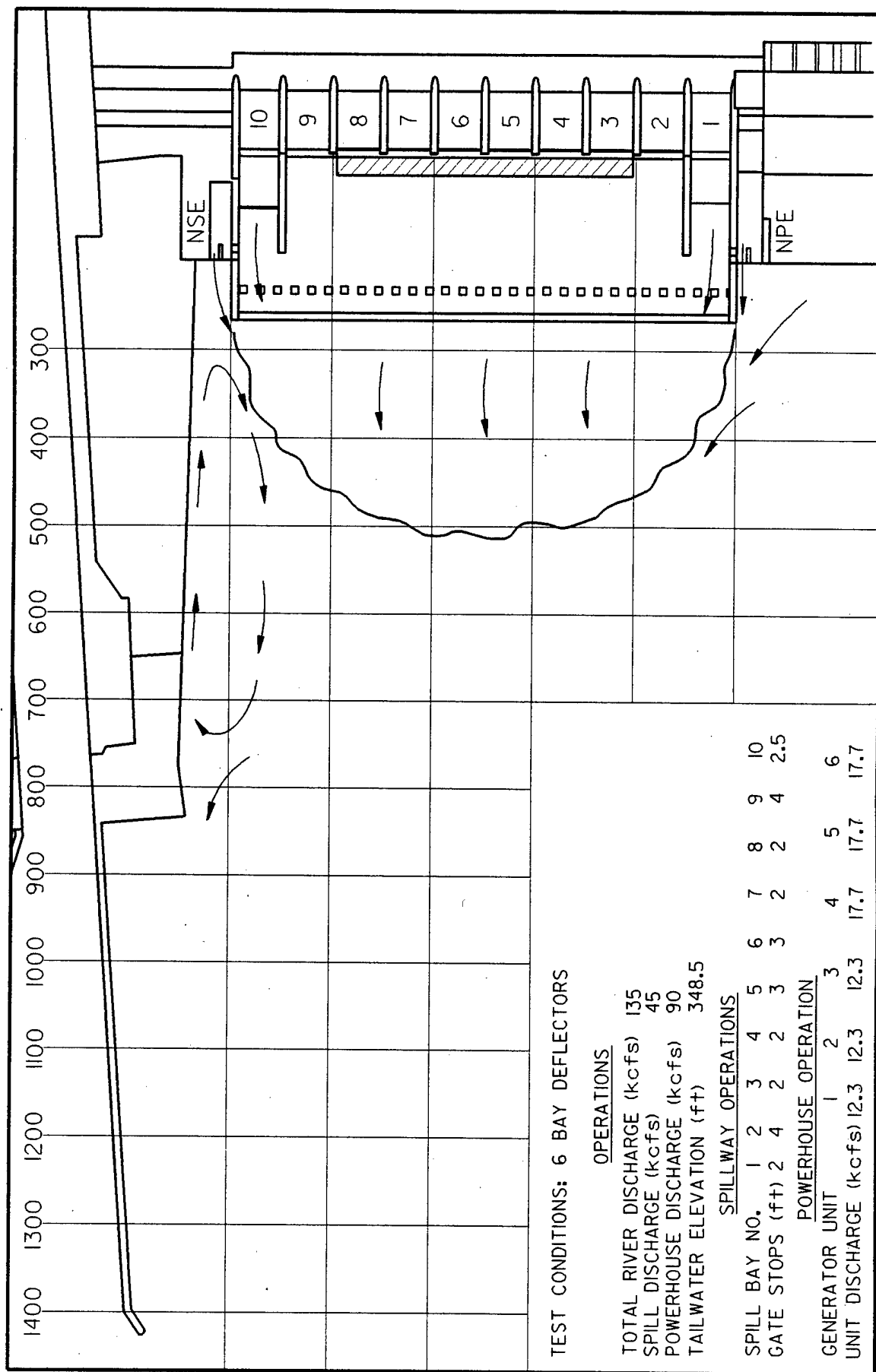
# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS



EXPERIMENT 24A

FIGURE 13

# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS



EXPERIMENT 21A

original hydrographed by J. H. ...

FIGURE 14

# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS

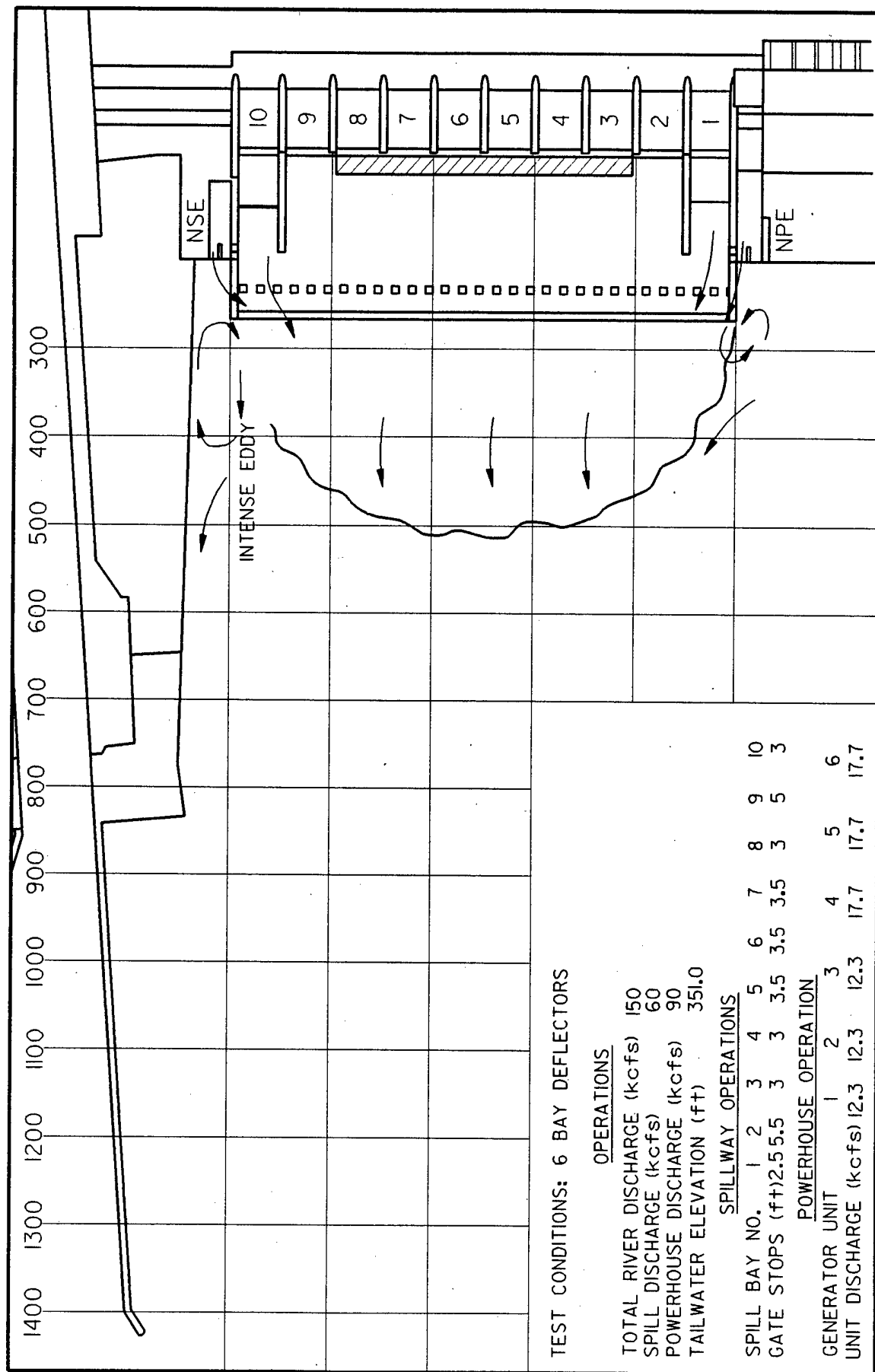
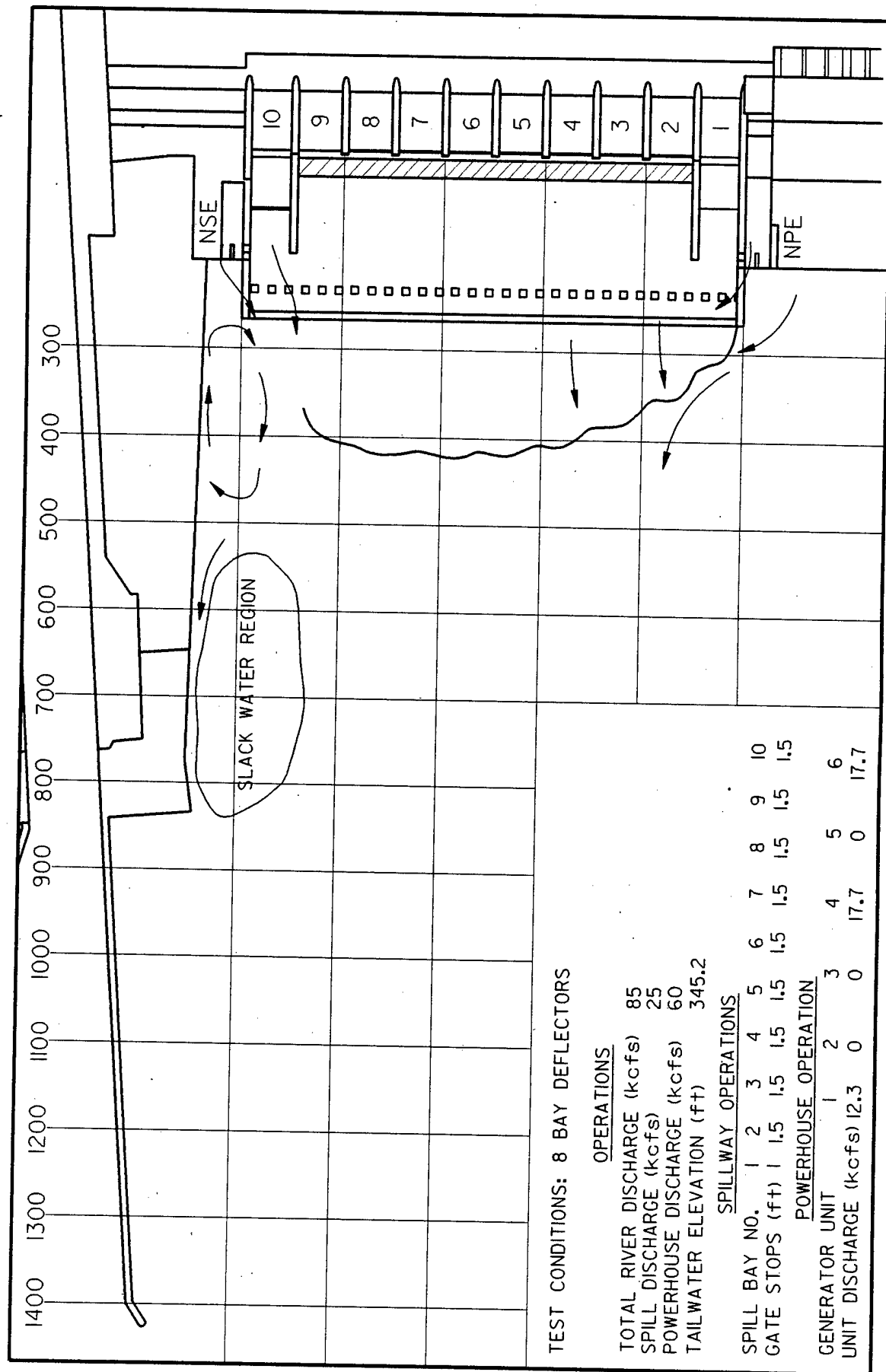


FIGURE 15

# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS



EXPERIMENT 15

FIGURE 16

# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS

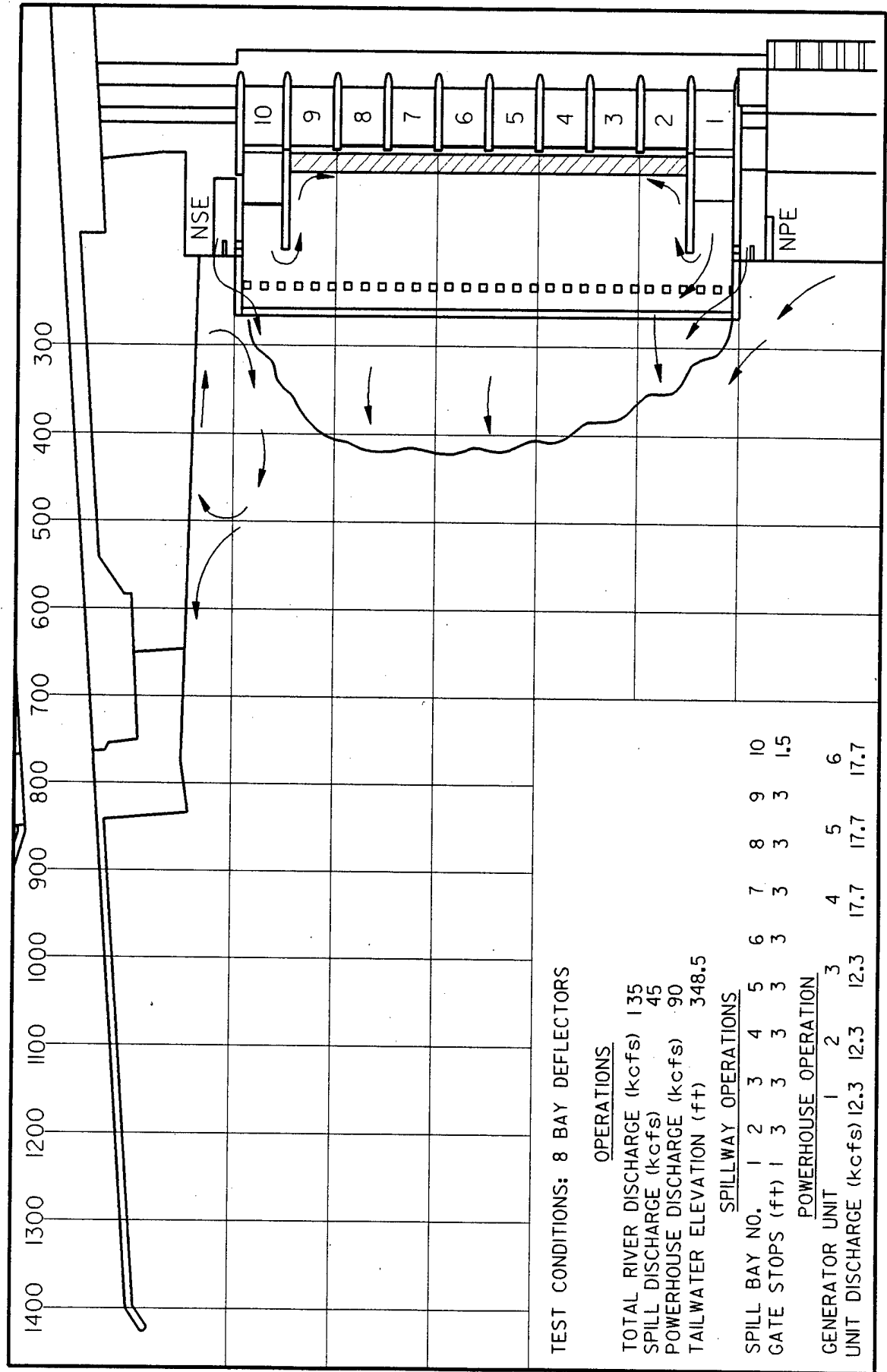


FIGURE 17

# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS

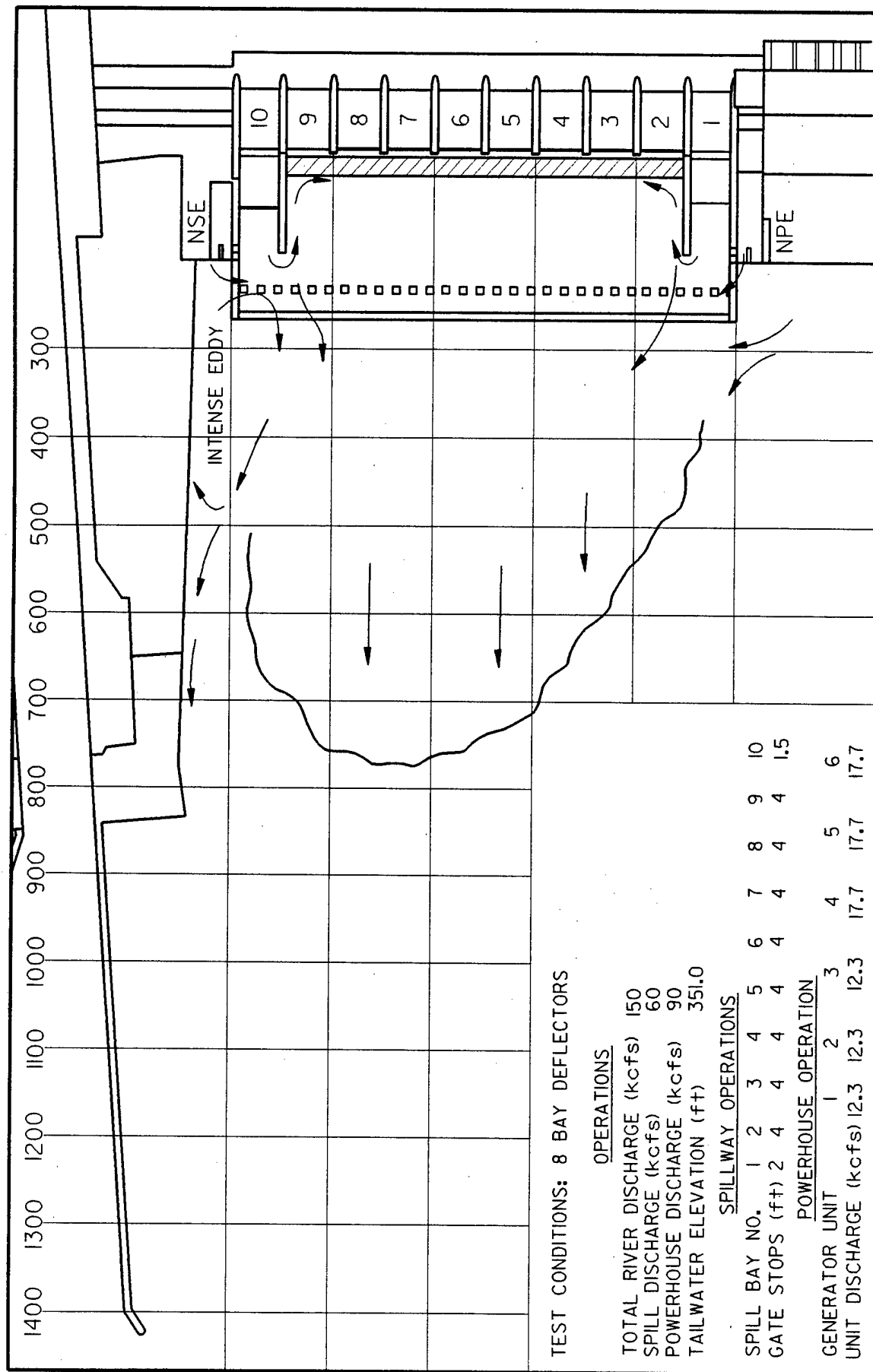
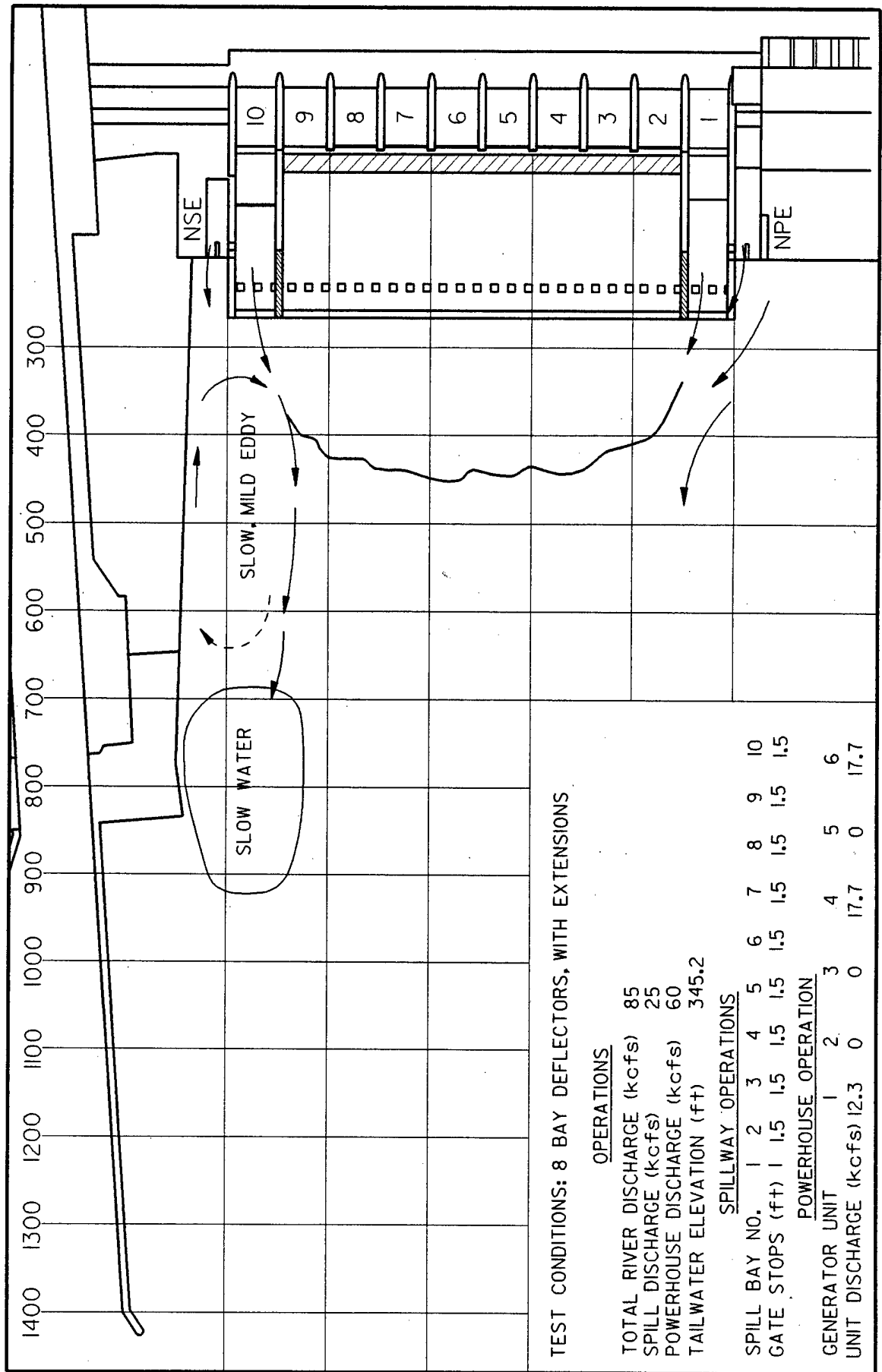


FIGURE 18

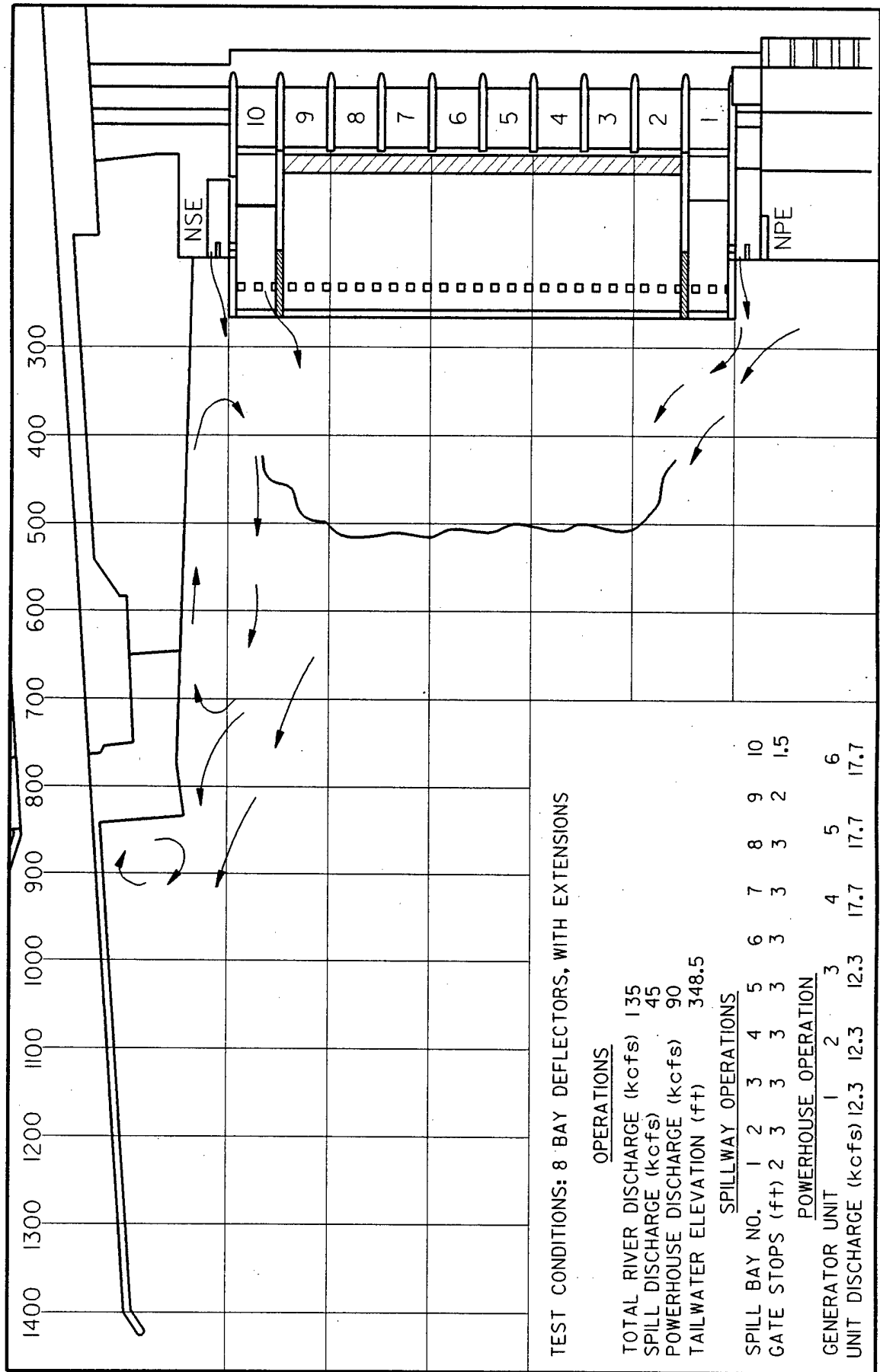
# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS



EXPERIMENT 15A

FIGURE 19

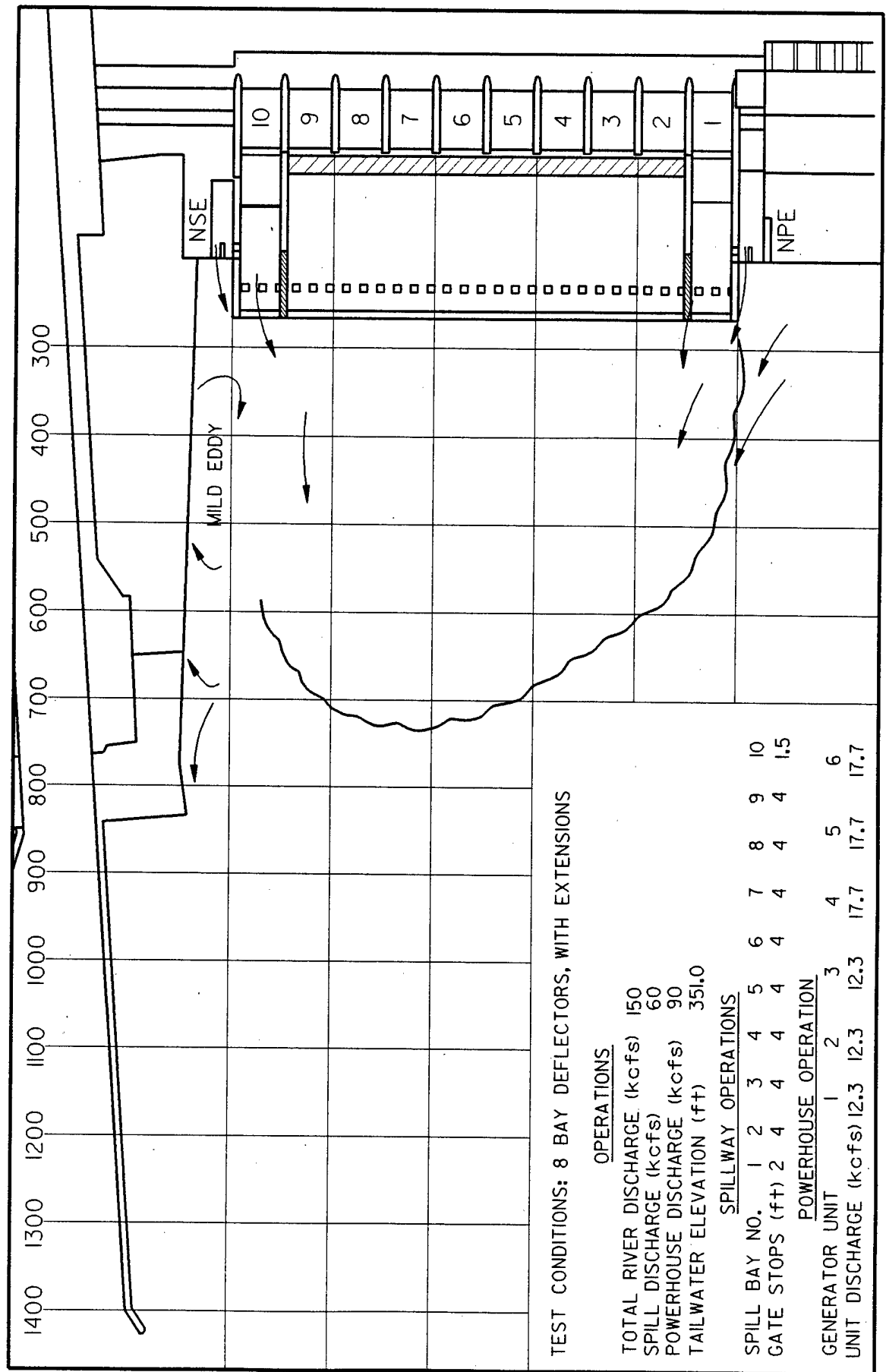
# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS



EXPERIMENT 11A

FIGURE 20

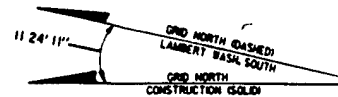
# ICE HARBOR DAM 1:55 SCALE GENERAL MODEL SPILL DEFLECTOR TEST OBSERVATIONS



EXPERIMENT 12A

FIGURE 21

## PLATES



PARKING  
AREA

ICE HARBOR DAM

BOAT  
DOCK

C.B.L. 25+82.00=  
NAV. LOCK 24+00.00

SPILLWAY

STILLING BASIN

(86' X 675')  
NAVIGATION LOCK

N. SHORE  
FISH LADDER

NORTH SHORE ACCESS ROAD

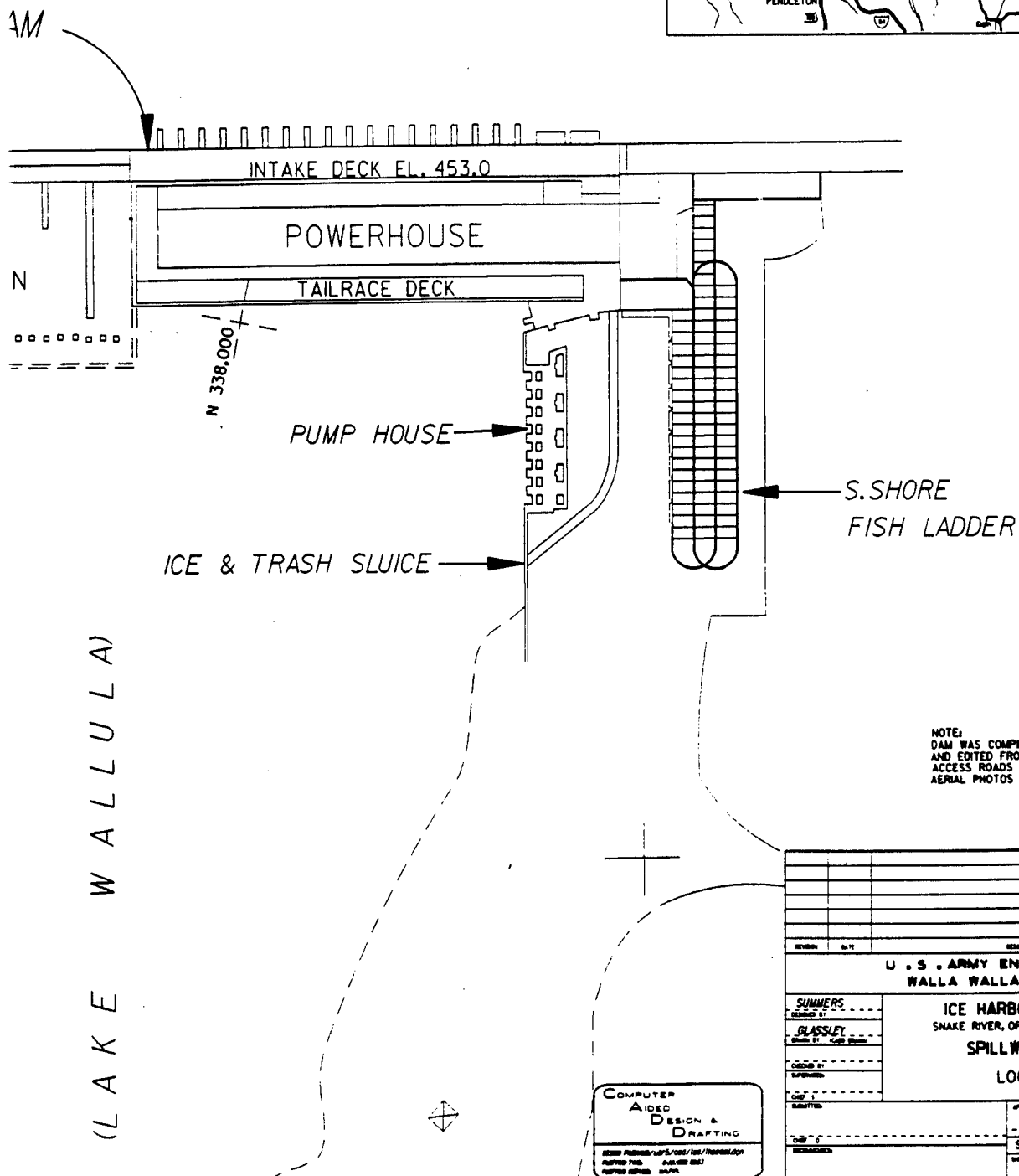
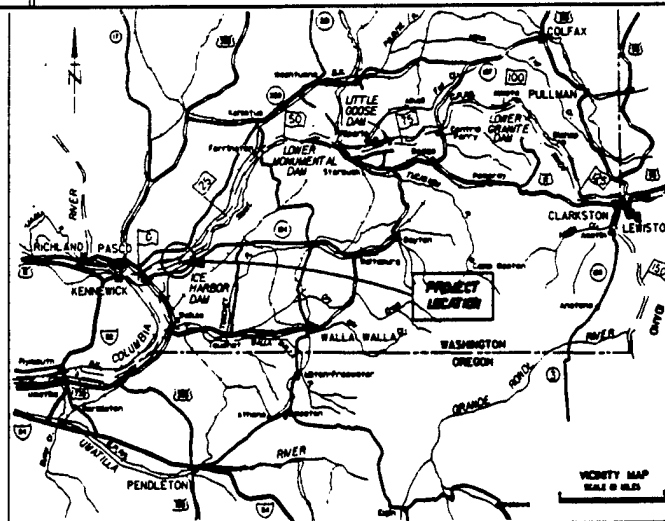
FRANKLIN CO.

WALLA WALLA CO.

(L A K E W A L L U L A)

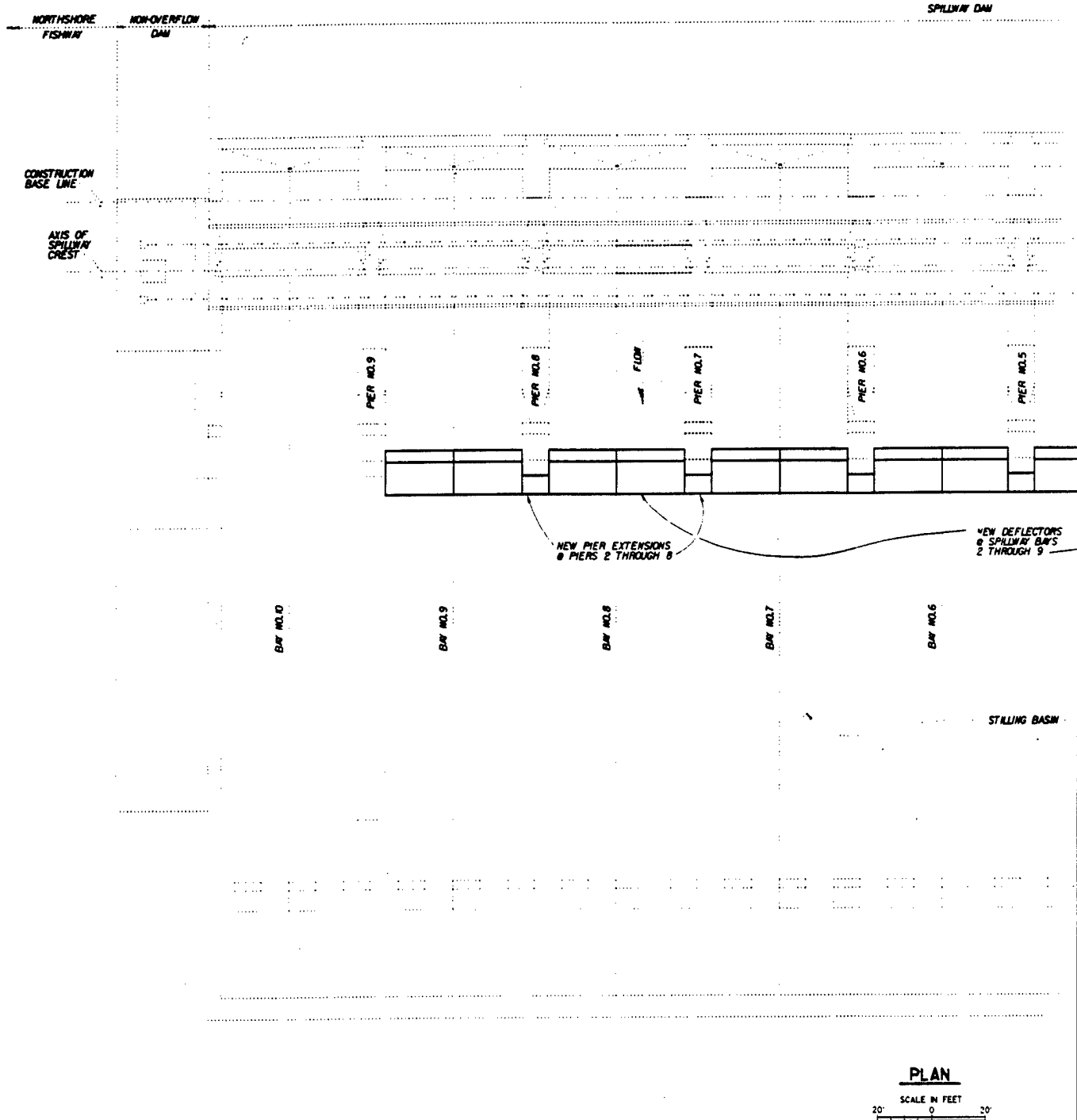
T. S. J. E.

ORD. NORTH (DASHED)  
LAMBERT BASAL SOUTH  
ORD. NORTH  
ASTRUCION (SOLID)



NOTE:  
DAM WAS COMPILED FROM CONTRACT SHEETS  
AND EDITED FROM AERIAL PHOTOS.  
ACCESS ROADS WERE COMPILED FROM  
AERIAL PHOTOS AND ARE ONLY APPROX.

U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
SUMMERS DESIGNED BY	ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO SPILLWAY DEFLECTORS LOCATION MAP
GLASSLEY CHECKED BY	
DATE	
SCALE AS SHOWN (INV. NO.)	



①



EXISTING STRUCTURE  
NEW STRUCTURE

[illegible]

## UE ENGINEERING PAYS

PLATE 2

EL 3540

PIER EXTENS

44-0%

▽ EL 347.2  
= SEE NOTE▽ EL 339.5-345.0 NORMAL  
= OPERATING RANGE

▽ EL 337.0 MINIMUM

NEW DEFLECTOR  
@ SPILLWAY BAYS  
2 THROUGH 9

50'-0" RADIUS

178'-0"

8'-0"

42'-0"

EL 346.0

EL 342.0

EL 304.0

①

## LEGEND

..... EXIS  
———— NEW

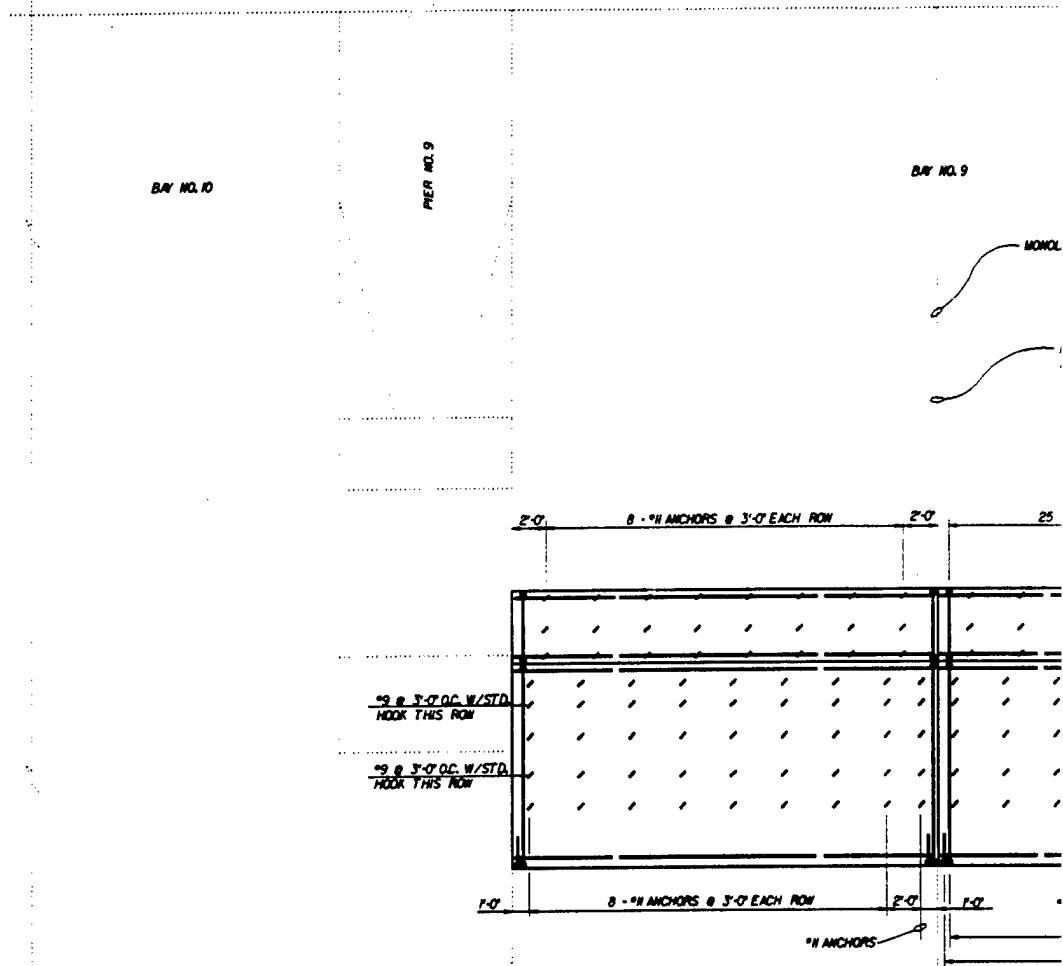
VALUE ENGINEER



EXISTING STRUCTURE  
NEW STRUCTURE

[www.fishbase.org/ur5/cot/lat/limon3.asp](http://www.fishbase.org/ur5/cot/lat/limon3.asp)  
 RPTED FRM 2-20-05 GMS  
 RPTED FRM 2-20-05 GMS

APPROVAL		DATE	DESCRIPTION	CHRG.	APPR.
<p align="center"><b>U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON</b></p>					
<b>SUMMERS</b> ----- <small>DESIGNED BY</small>		<p align="center"><b>ICE HARBOR LOCK &amp; DAM</b></p>			
<b>GLASSLEY</b> ----- <small>CHECKED BY</small>		<p align="center">SHAKE RIVER, OREGON, WASHINGTON &amp; IDAHO</p>			
<b>J.</b> ----- <small>CONSTRUCTION</small>		<p align="center"><b>SPILLWAY DEFLECTORS</b></p>			
<b>W.</b> ----- <small>CONSTRUCTION</small>		<p align="center"><b>SPILLWAY &amp; STILLING BASIN</b></p>			
<b>W.</b> ----- <small>CONSTRUCTION</small>		<p align="center"><b>SECTION</b></p>			
<small>SUBMITTER</small>		<small>APPROVED</small>		<small>DATE</small>	
<small>DATE</small>		<p align="center"><b>SCALE AS SHOWN INV. NO.</b></p>		<small>FILE NO.</small>	
<small>CONSTRUCTION</small>		<small>INVEST. NO.</small>		<small>FILE NO.</small>	



NOTE:  
REINFORCEMENT SHOWN IS TYPICAL FOR  
BAYS 2 THROUGH 9 AND PIERS 2 THROUGH 8.

NOTES:

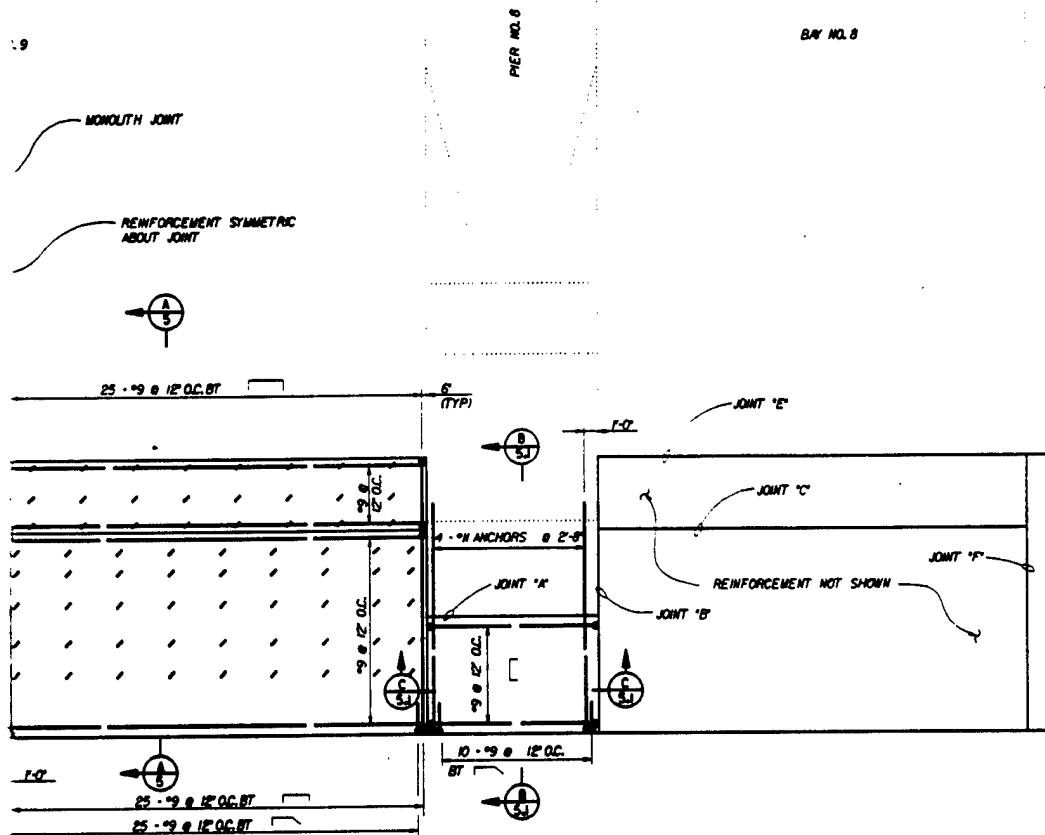
KNOWN EMBEDDED ITEMS IN AREA OF CONSTRUCTION

1. 60" DIAMETER PENSTOCK AND 16" DIAMETER PIPE  
TEMPORARY FISH BYPASS - LOCATED IN BAY 8  
SEE SHEET NO. 13 & 31
2. EMBEDDED SHEET PILE IN PIERS 6 & 7  
SEE SHEET NO. 8, 12, 13, 19, 25, 33 & 34
3. LOW BAY REMOVEABLE LIP IN BAYS 2 THRU 7  
SEE SHEET NO. 8, 14, 15 & 16
4. EMBEDDED ANCHOR BOLTS - PIERS 1 THRU 7  
SEE SHEET NO. 8, 12, 16 & 32
5. EMBEDDED BLACK PIPE IN STILLING BASIN  
SEE SHEET NO. 25, 27 & 28
6. PIER REINFORCEMENT  
SEE SHEET NO. 18, 19, 20, 22, 23, 24, 26, 29 & 32
7. STILLING BASIN REINFORCEMENT  
SEE SHEET NO. 25, 27 & 28

①

DEFLE

SCA  
12" 0'

**DEFLECTOR PLAN**

SCALE IN FEET  
12" 0 5'

**LEGEND**

EXISTING STRUCTURE  
NEW STRUCTURE



REVISION		DATE	REVISION	DATE	APPR.
U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON					
SUMMERS DESIGNED BY		ICE HARBOR LOCK & DAM SHAKE RIVER, OREGON, WASHINGTON & IDAHO			
GLASSLEY CHECKED BY		SPILLWAY DEFLECTORS			
N. CHECKED BY		DEFLECTOR PLAN			
APP'D BY		APPROVED			
SCALE AS SHOWN (BY NO.)		SCALE AS SHOWN (BY NO.)			
SHEET NO.		PL. NO.			

SPILLWAY CREST EL.

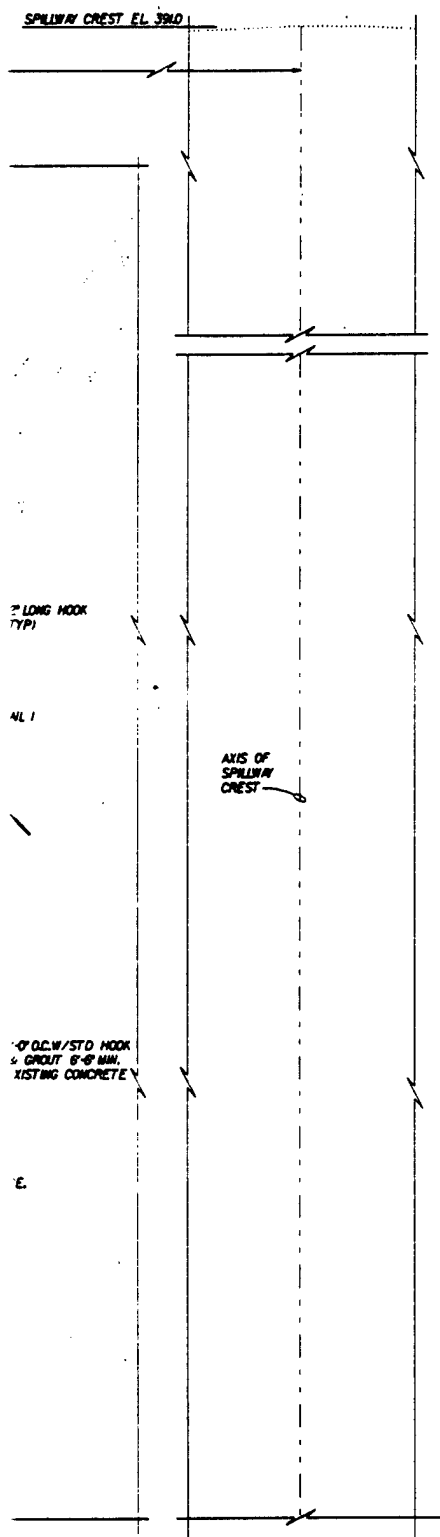


SCALE IN FEET

12" 0 1' 2' 3'

①

SPILLWAY CREST EL. 394.0

2" LONG HOOK  
(TYP)

4#1

AXIS OF  
SPILLWAY  
CREST4" O.D. W/STD HOOK  
& GROUT 8"-8" DIA.  
EXISTING CONCRETE

E.

15'-0" RADIUS CURVE &  
EXISTING SPILLWAY SURFACE  
ARE NOT TANGENTIAL

EL. 342.53

175°

\* SEE NOTE 2

## DETAIL 1

SCALE IN FEET

0' 3' 6' 9' 0'

## NOTES:

1. GEOMETRY AND REINFORCEMENT SHOWN ARE TYPICAL FOR BAYS 2 THROUGH 9.
2. THE EXISTING GEOMETRY AND FINAL GEOMETRY MAY VARY FROM THE THEORETICAL GEOMETRY SHOWN DUE TO AS BUILT GEOMETRY. THE CONTROLLING GEOMETRY FOR CONSTRUCTION IS AS FOLLOWS:
  - SET THE DOWNSTREAM FACE OF THE DEFLECTORS 6'-9" DOWNSTREAM OF THE EXISTING PIER FACE.
  - TOP OF DEFLECTORS SHALL BE AT EL. 338.0.
  - BOTTOM ELEVATION OF DEFLECTORS SHALL BE EL. 322.95.
  - INTERSECTION OF TOP EDGE OF DEFLECTOR & EXISTING SPILLWAY SHALL BE AT EL. 342.53.
  - A 15'-0" RADIUS SHALL BE USED TO TRANSITION FROM THE EXISTING SPILLWAY SURFACE TO THE TOP OF THE DEFLECTORS AT EL. 338.0.
3. THE TWO BARS LOCATED IN THE IMMEDIATE VICINITY OF THE 60" PENSTOCK (SEE NOTE 1, SHEET 4) SHALL BE DRILLED AND GROUTED 5'-0" INTO EXISTING CONCRETE.
4. THE THREE BARS LOCATED IN THE IMMEDIATE VICINITY OF THE 60" PENSTOCK AND 16" PIPE (SEE NOTE 1, SHEET 4) SHALL NOT BE INSTALLED. AN ADDITIONAL BAR SHALL BE INSTALLED 18" NORTH OF THE NORTH EDGE OF THE 16" PIPE. AN ADDITIONAL BAR SHALL ALSO BE INSTALLED 18" SOUTH OF THE SOUTH EDGE OF THE 60" PENSTOCK.

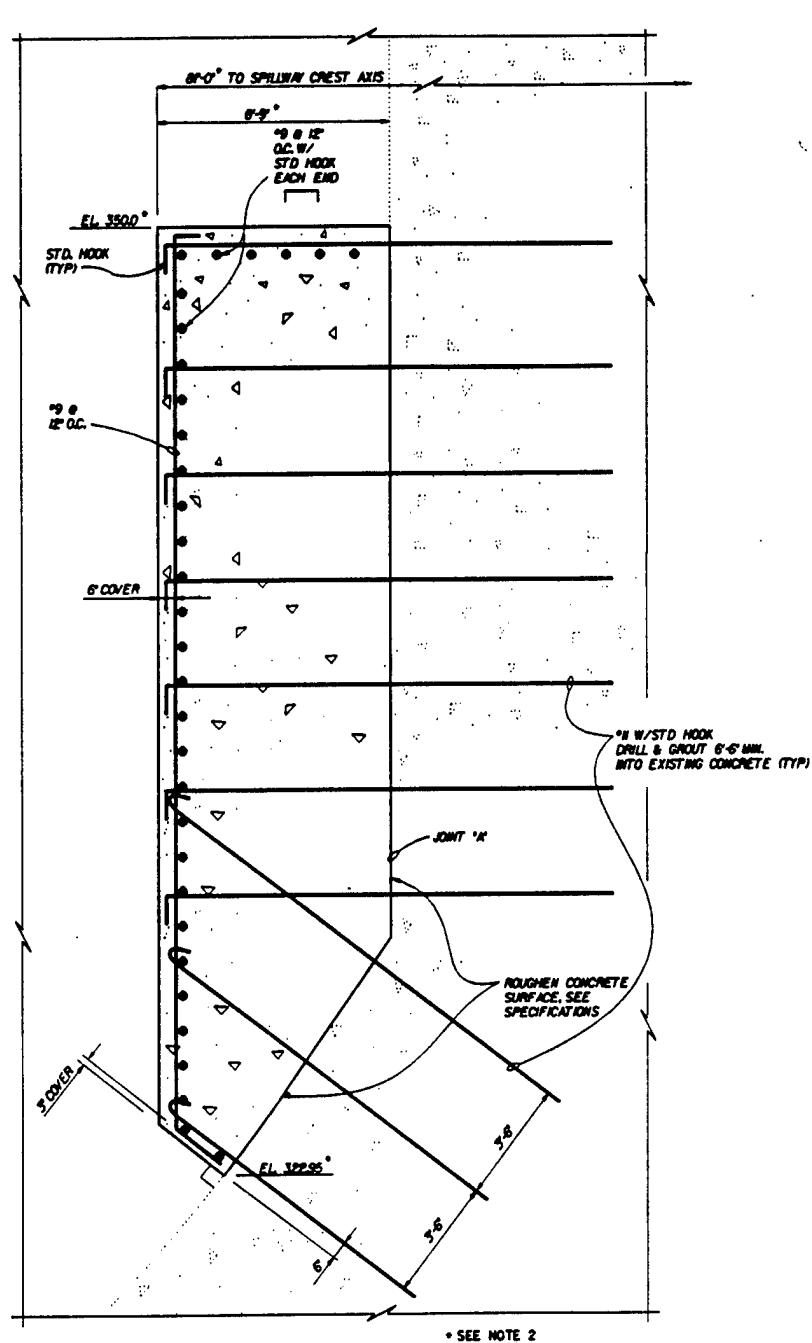
## LEGEND

..... EXISTING STRUCTURE  
 \_\_\_\_\_ NEW STRUCTURE

COMPUTER  
AIDED  
DESIGN &  
DRAFTING

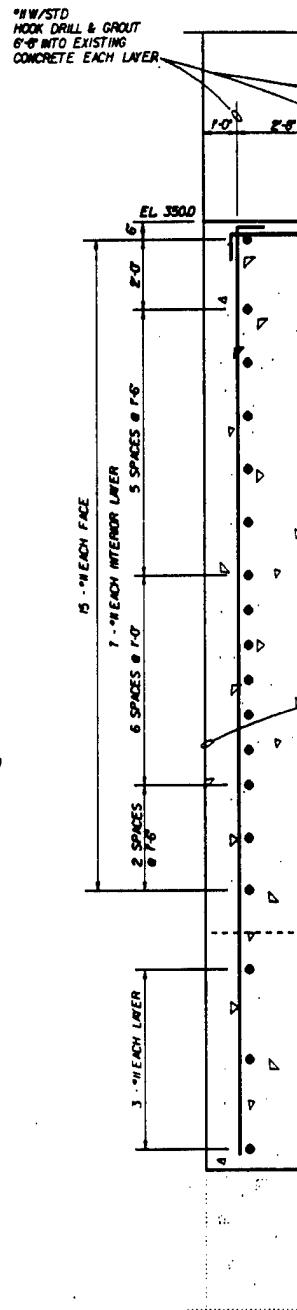
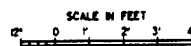
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 DRAFTING: [REDACTED]  
 CHECKED: [REDACTED]  
 APPROVED: [REDACTED]

REVISION		DATE	DESCRIPTION	DESIGN	APPROVED
U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON					
SUMMERS		ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO			
GLASSLEY		SPILLWAY DEFLECTORS			
H		DEFLECTOR			
SPILLWAY SECTION		SCALE AS SHOWN BY NO.			
DATE		FILE NO.			

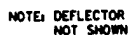


TYPICAL PIER EXTENSION - SECTION B

4



TYPICAL PIER



4

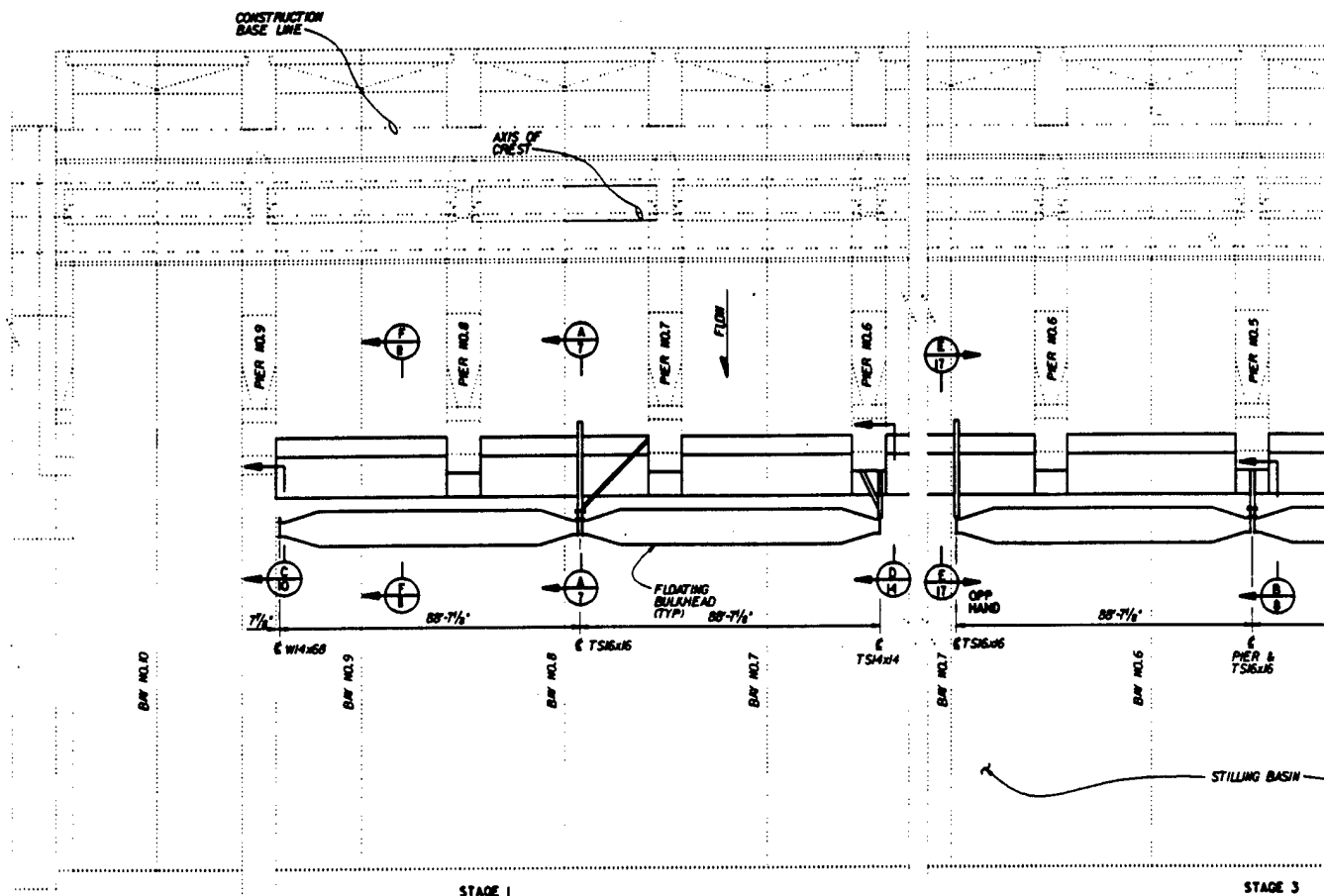


**COMPUTER  
AIDED  
DESIGN &  
DRAWING**

DATE FORWARDED: 10/3/88/10/10/88/10/10/88  
FORWARDED TO: 10-10-88/10-10-88  
FORWARDED BY: 10-10-88

1. GEOMETRY AND REINFORCEMENT SHOWN ARE TYPICAL FOR PIERS 2 THROUGH 8.
2. THE EXISTING GEOMETRY AND FINAL GEOMETRY MAY VARY FROM THE THEORETICAL GEOMETRY SHOWN DUE TO AS BUILT GEOMETRY. THE CONTROLLING GEOMETRY FOR CONSTRUCTION IS AS FOLLOWS:
  - SET THE DOWNSTREAM FACE OF THE PIER EXTENSIONS 6'-9" DOWNSTREAM OF THE EXISTING PIER FACE.
  - TOP OF PIER EXTENSIONS SHALL BE AT EL. 350.0.
  - BOTTOM ELEVATION OF PIER EXTENSIONS SHALL BE EL. 322.95.

## VALUE ENGINEERING PAYS



DEWATERING -

SCALE IN FEET  
0 10

STAGE 1 - LIST OF QUANTITIES

NO.	QUAN.	COMMENT
MK-1	1	
MK-2	1	
MK-3	1	
MK-4	1	
MK-8	1	
MK-9	1	
MK-12	6	
MK-13	2	ONE AS SHOWN & ONE SBL
MK-14	2	ONE AS SHOWN & ONE OPP. HAND

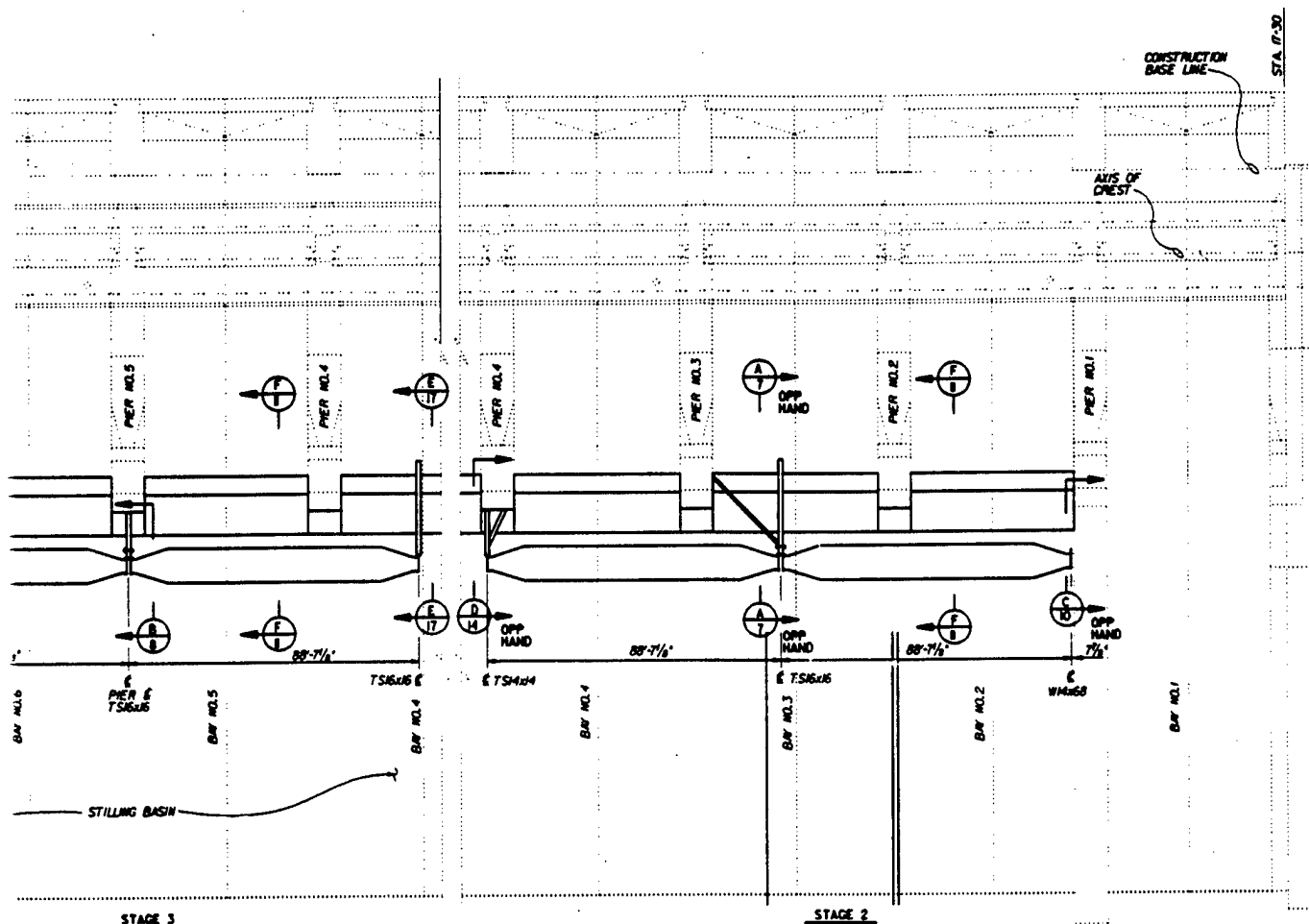
STAGE 3 - LIST OF QUANTITIES

NO.	QUAN.	COMMENT
MK-1	1	REUSE
MK-2	1	
MK-5	1	
MK-6	1	
MK-7	1	
MK-10	2	ONE AS SHOWN & ONE OPP. HAND
MK-11	2	ONE AS SHOWN & ONE OPP. HAND
MK-12	6	REUSE
MK-13	2	REUSE
MK-14	2	REUSE

STAGE 2 - LIST OF QUANTITIES

NO.	QUAN.	COMMENT
MK-1	1	REUSE
MK-2	1	
MK-3	1	
MK-4	1	OPP. HAND
MK-8	1	OPP. HAND
MK-9	1	OPP. HAND
MK-12	6	REUSE
MK-13	2	REUSE
MK-14	2	REUSE

①



## DEWATERING - PLAN

SCALE IN FEET  
10' 0' 10'

## NOTES:

- SEE NOTES ON SHEET NO. 4 FOR EXISTING EMBEDDED ITEMS.
- THE DEWATERING SYSTEM SHOWN HAS BEEN DESIGNED FOR TAILWATER UP TO EL. 348.0.
- ALL ELEMENTS AND SUPPORTS FOR THE DEWATERING SYSTEM SHOWN HAVE BEEN DESIGNED FOR DEWATERING LOADS ONLY. NO ADDITIONAL LOADS ARE ALLOWED. THIS SYSTEM SHALL BE ISOLATED FROM FORMS, SAFFOLDING, ETC. CARE MUST BE TAKEN IN PLACING CONCRETE TO ENSURE NO SUDDEN OR DIFFERENTIAL LOADING OF CONCRETE AGAINST THE SUPPORTS OCCUR.
- TWO EXISTING FLOATING BULKHEADS ARE AVAILABLE FOR DEWATERING. A 24' TALL BULKHEAD AT LOWER GRANITE (SHEETS 45-48) AND A 23' TALL BULKHEAD AT LITTLE GOOSE (SHEETS 49-53). THE 23' TALL BULKHEAD IS SHOWN THROUGHOUT THE DEWATERING DRAWINGS.
- ALL STEEL PLATES AND ROLLED SHAPES SHALL BE ASTM A572 GRADE 50 EXCEPT STRUCTURAL TUBING SHALL BE ASTM A500 GRADE B. IF STRUCTURAL SHAPES & TUBING SPECIFIED ARE NOT READILY AVAILABLE THEY SHALL BE FABRICATED FROM A572 GRADE 50 PLATE.
- WELD FILLER METAL SHALL HAVE A MINIMUM TENSILE STRENGTH OF 70 KSI.
- ALL ANCHOR BOLTS SHALL BE UNDERCUT ANCHORS OF ASTM A993 B7 BOLTING MATERIAL. AFTER GROUT PADS HAVE ATTAINED A MINIMUM COMPRESSIVE STRENGTH OF 5000 PSI, ALL ANCHORS SHALL BE TENSIONED TO 85 KSI WITH A MINIMUM TENSION REMAINING AFTER SEATING OF 65 KSI.
- DEBRIS AND/OR EROSION MAY BE PRESENT. CONTRACTOR IS REQUIRED TO REMOVE ALL OVERBURDEN IN VICINITY OF DEWATERING SYSTEM PRIOR TO FABRICATION. THE CONTRACTOR SHALL FIELD VERIFY EXISTING GEOMETRY AND ADJUST GEOMETRY OF THE DEWATERING SYSTEM ACCORDINGLY. WHERE EROSION IS PRESENT AT SUPPORTS, THE SUPPORTS MUST BE EXTENDED AND GROUT PAD THICKNESS SHALL NOT BE GREATER THAN 2" IN THICKNESS.
- THE DEWATERING SYSTEM IS NOT WATER TIGHT. IT IS THE CONTRACTOR'S RESPONSIBILITY, TO PROVIDE ADDITIONAL SEALING AND PUMPS TO CONTROL LEAKAGE.

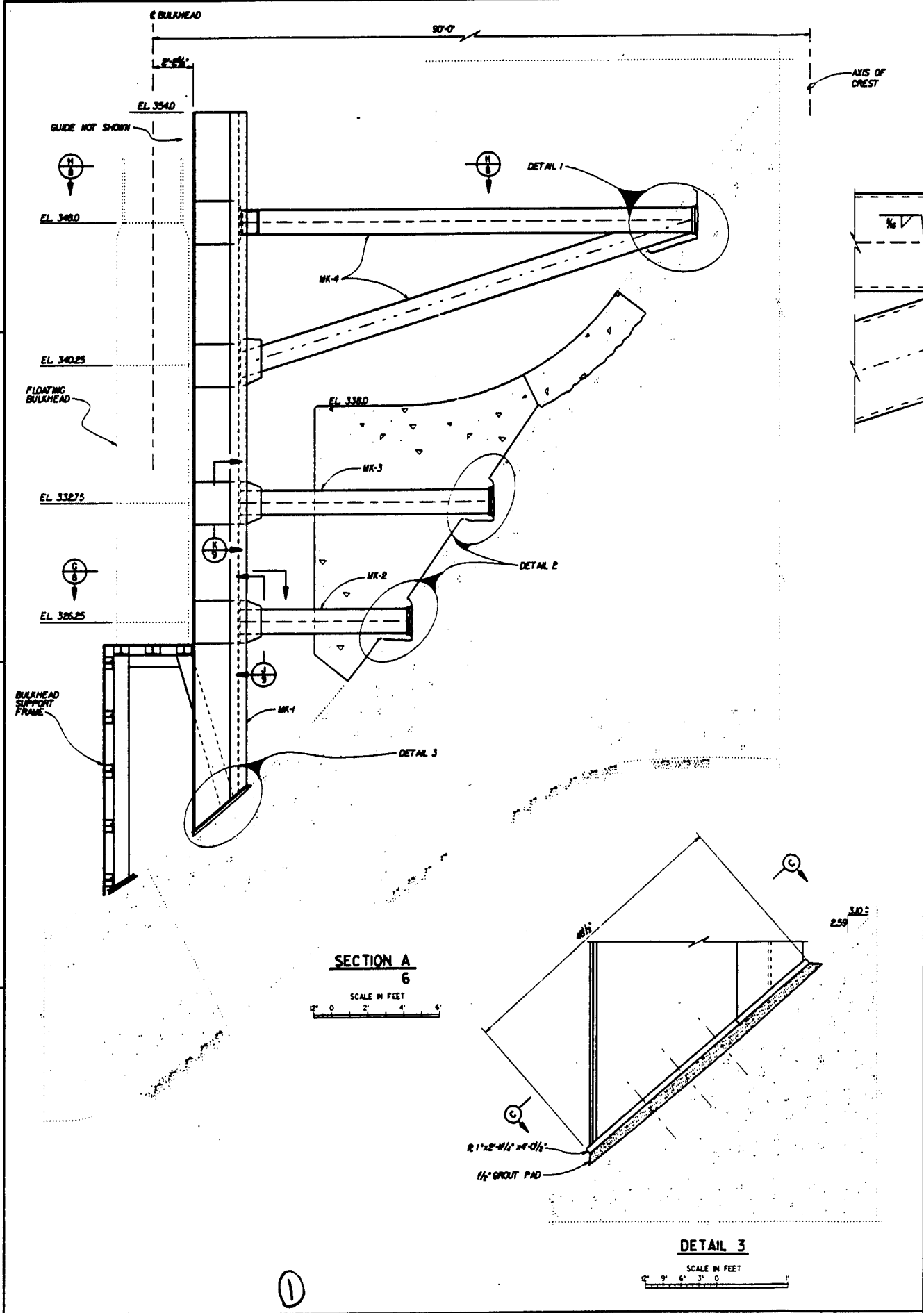
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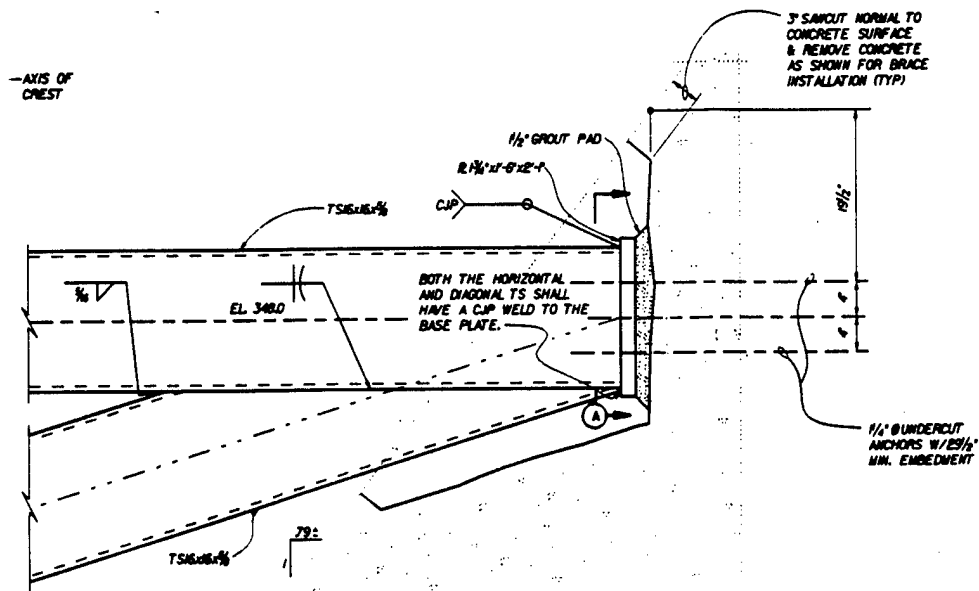
EXISTING STRUCTURE  
NEW STRUCTURE

COMPUTER  
AIDED  
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DRAWING

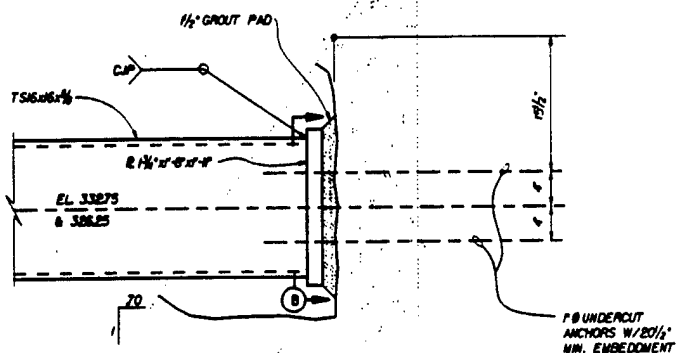
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U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
ICE HARBOR LOCK & DAM SHAKE RIVER, OREGON, WASHINGTON & IDAHO SPILLWAY DEFLECTORS OPTIONAL DEWATERING METHOD PLAN	
SUMMERS [illegible]	DATE: [illegible]
GLASSLEY [illegible]	DATE: [illegible]
SCALE AS SHOWN BYV. NO.	

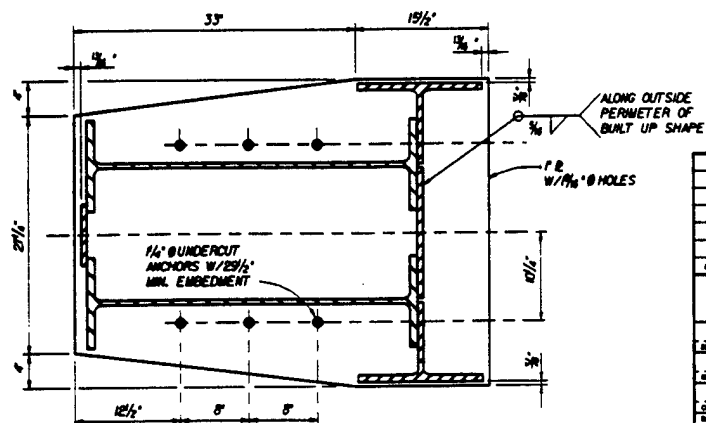




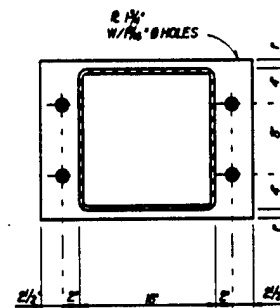
DETAIL 1

SCALE IN FEET  
0' 3' 6' 9'

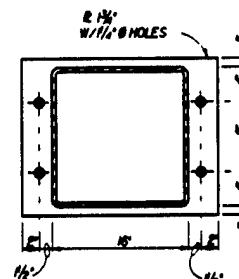
DETAIL 2

SCALE IN FEET  
0' 3' 6' 9'

SECTION C

SCALE IN FEET  
0' 3' 6' 9'

SECTION A

SCALE IN FEET  
0' 3' 6' 9'

SECTION B

SCALE IN FEET  
0' 3' 6' 9'

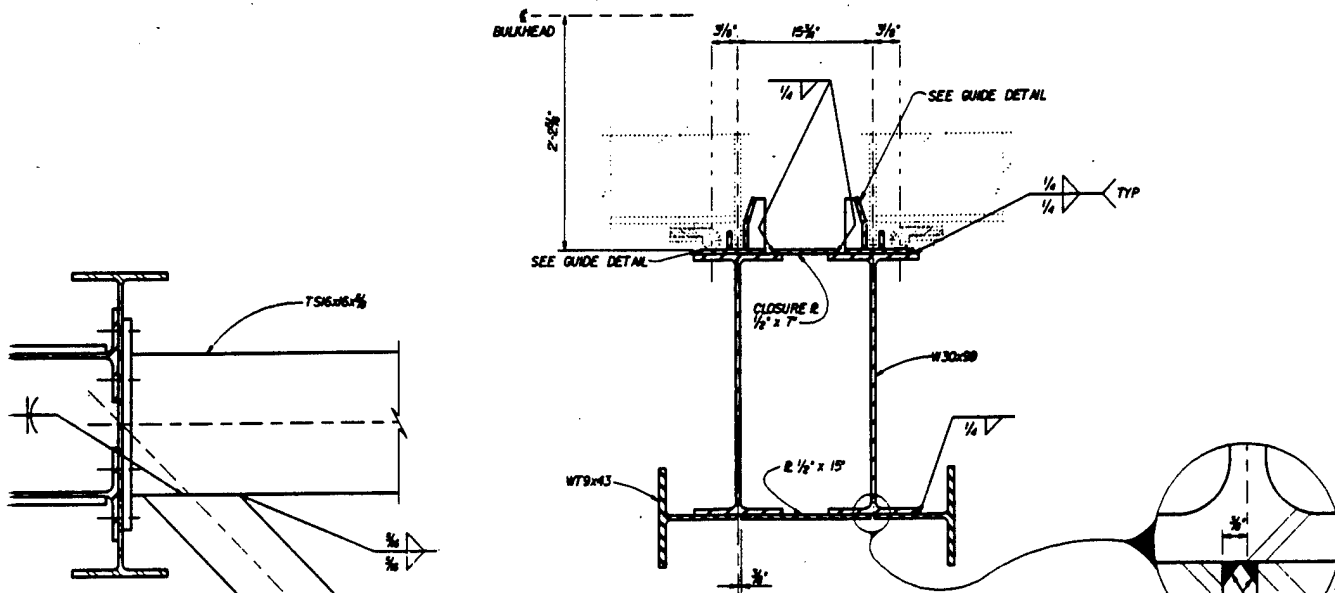
## LEGEND

..... EXISTING STRUCTURE

———— NEW STRUCTURE

U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
ICE HARBOR LOCK & DAM SHAKE RIVER, OREGON, WASHINGTON & IDAHO SPILLWAY DEFLECTORS	
OPTIONAL DEWATERING METHOD CENTER BRACE - SECTIONS AND DETAILS I	
SUMMERS DESIGNED BY BLASSLEY CHECKED BY J. L. DATE SCALE SHEET NO.	SCALE AS SHOWN INV. NO. SHEET NO.





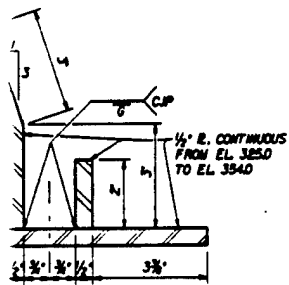
BUILT UP GIRDER - SECTION G  
MK-1

SCALE IN FEET  
12' 9' 6' 3' 0'

7.8

SECTION H

SCALE IN FEET

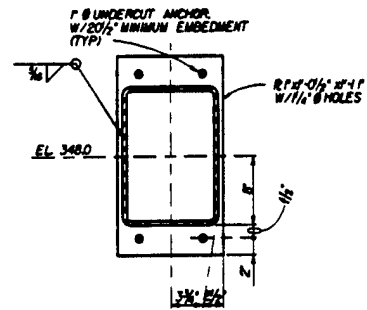


C W30x99

SIDE DETAIL

SCALE IN INCHES

1" = 6"



SECTION A

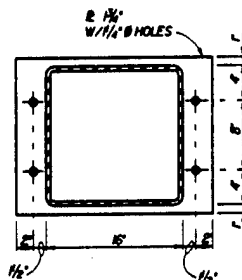
SCALE IN FEET

12' 9' 6' 3' 0'

LEGEND

EXISTING STRUCTURE

NEW STRUCTURE



SECTION C

SCALE IN FEET

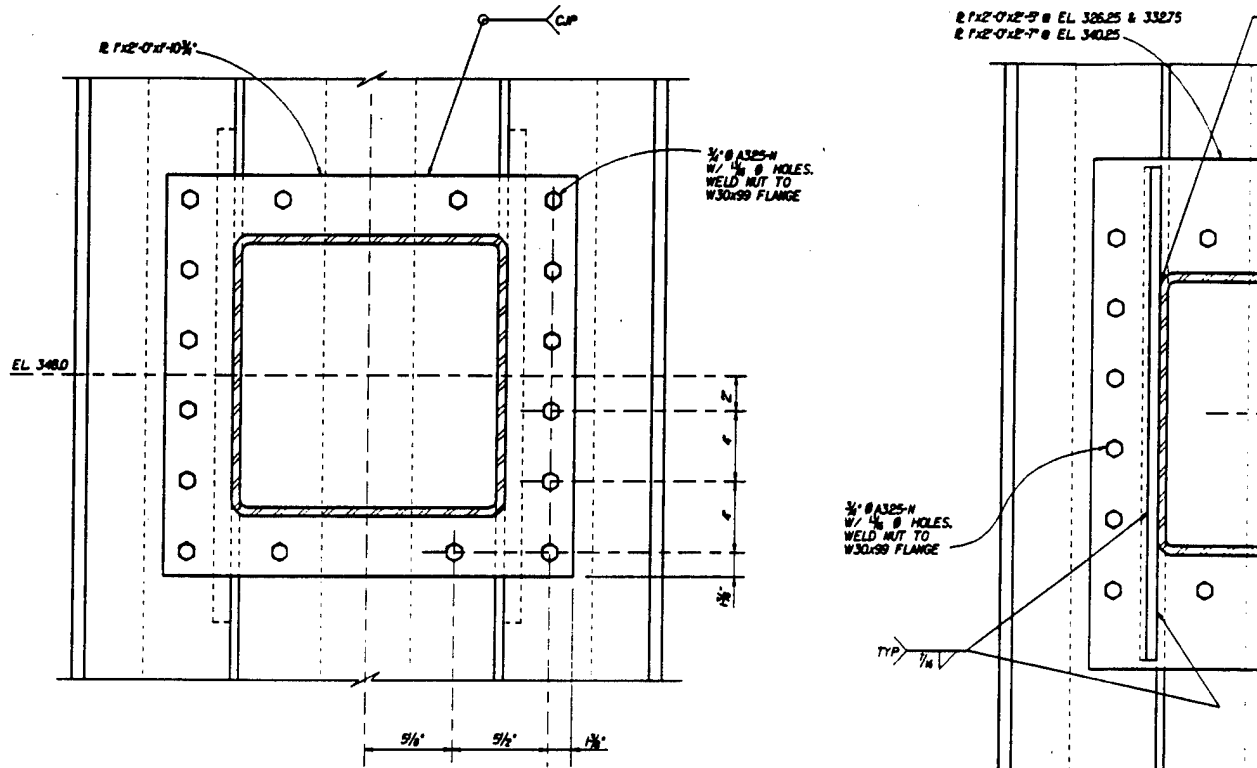
12' 9' 6' 3' 0'

COMPUTER  
AIDED  
DESIGN &  
DRAWING

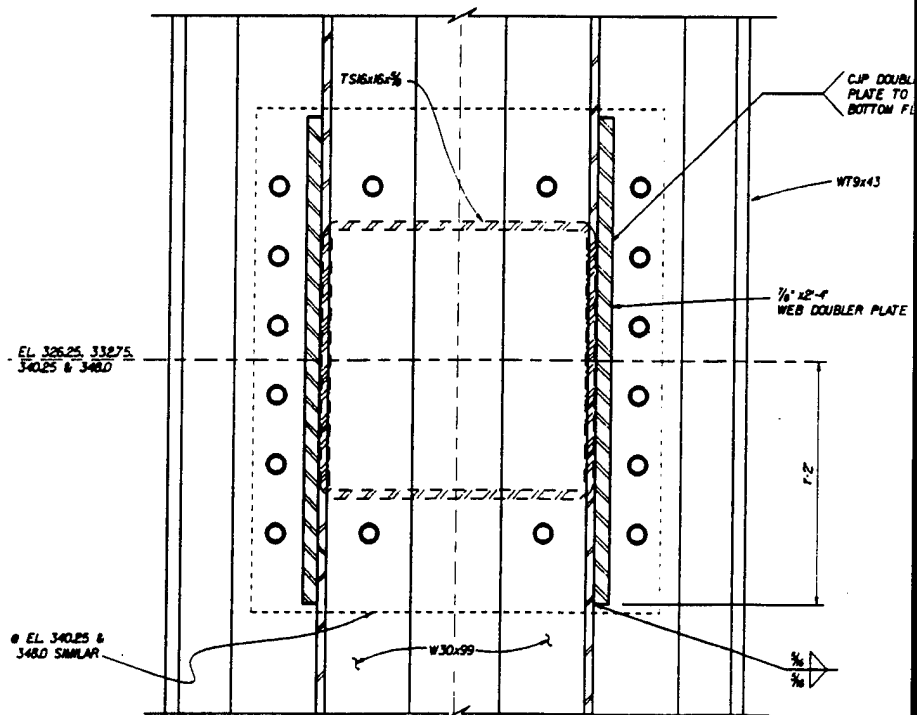
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CHECKED: [Name]  
DATE: [Date]

2

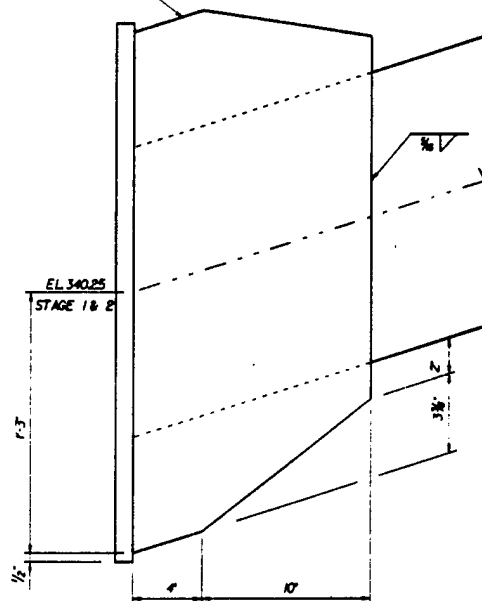
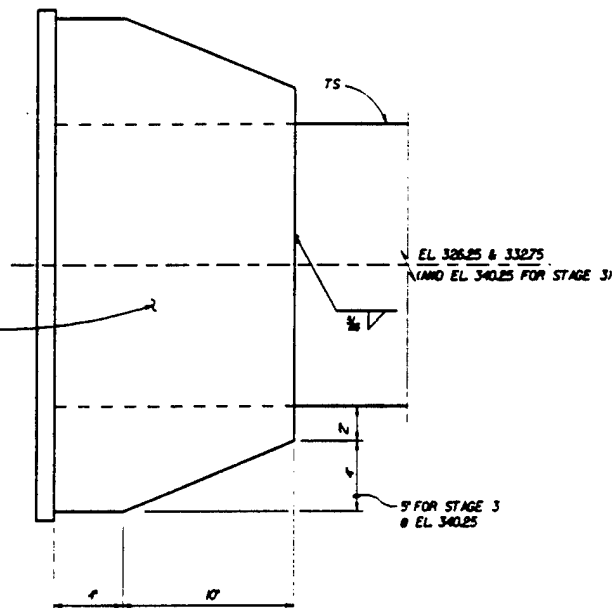
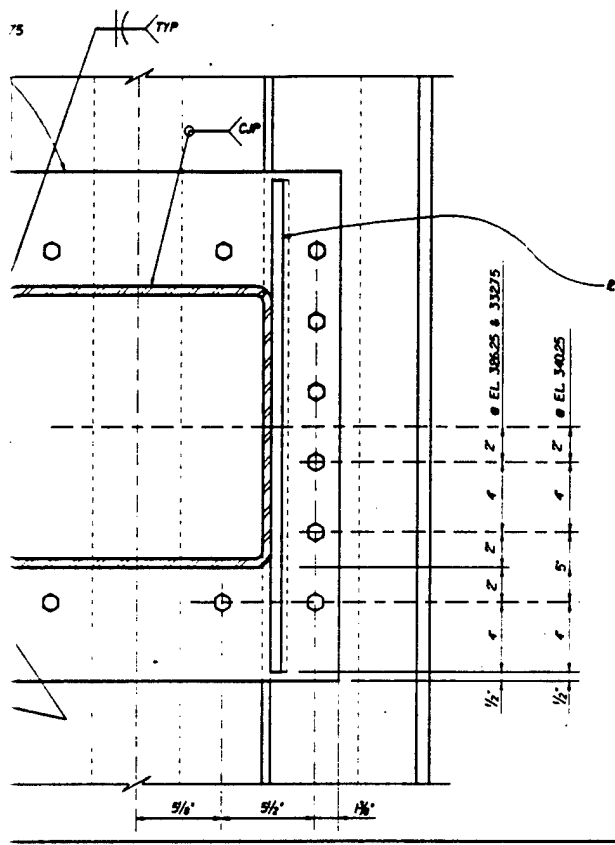
U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO	
SPILLWAY DEFLECTORS	
OPTIONAL DEWATERING METHOD CENTER BRACE - SECTIONS & DETAILS II	
SUMMERS DESIGNER	DATE
GLASSLEY CHECKED	DATE
H. DESIGNER	DATE
DATE	DATE
SCALE AS SHOWN INV. NO.	FILE NO.



SCALE IN FEET 7.8  
1" 9" 6" 3" 0"



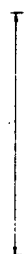
SCALE IN FEET 7  
1" 9" 6" 3" 0"



CP DOUBLER  
PLATE TO TOP &  
BOTTOM FLANGE

WTS#43

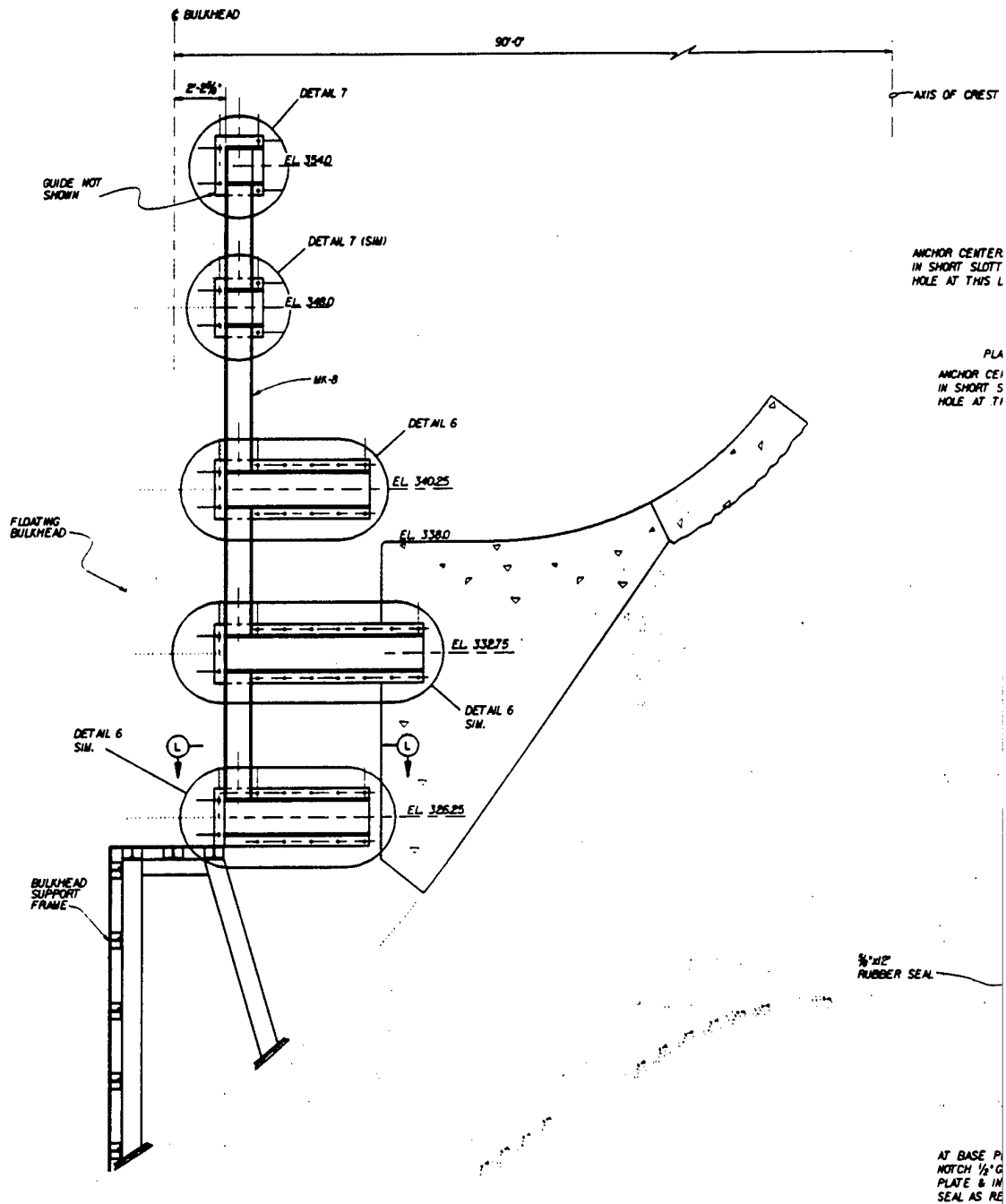
DOUBLER PLATE

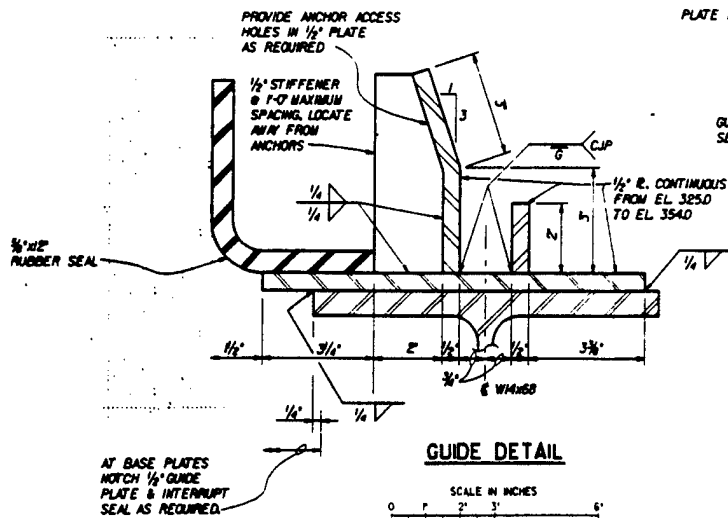
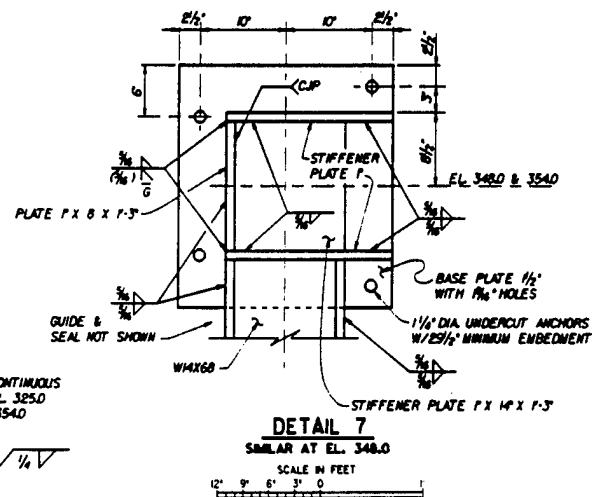
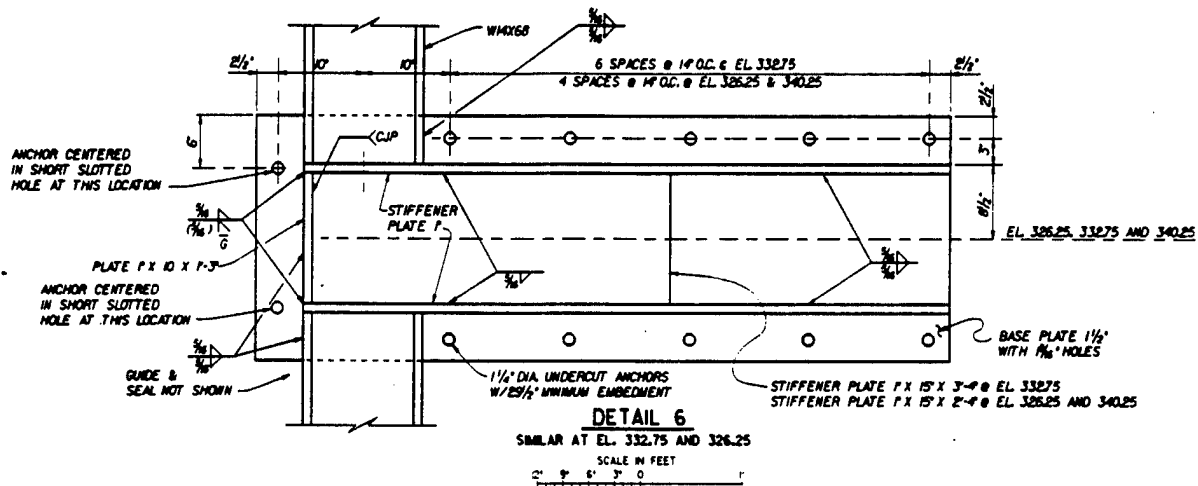
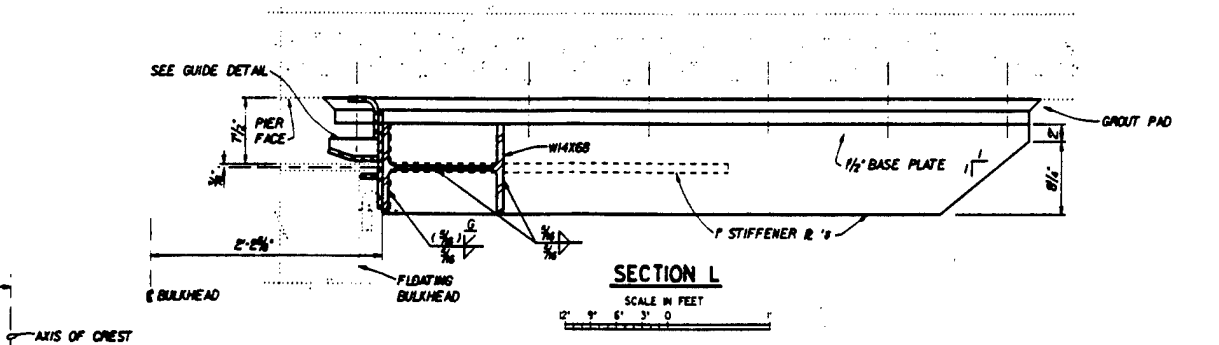


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REVISION	DATE	BY	CHKD.	APPR.
U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON				
ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO SPILLWAY DEFLECTORS OPTIONAL DEWATERING METHOD CENTER BRACE - SECTIONS & DETAILS II				
DESIGNED BY SUMMERS CHECKED BY GLASSLEY DATE: [blank] / [blank] / [blank]		DATE: [blank] / [blank] / [blank]		
SCALE AS SHOWN IN DIV. NO.		PAGE NO.		

SECTION C  
6SCALE IN FEET  
12' 0' 2' 4' 6'



### LEGEND

..... EXISTING FEATURES  
 \_\_\_\_\_ NEW FEATURES

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AIDED  
DESIGN &  
DRAWING

[illegible]

U. S. ARMY ENGINEER DISTRICT  
WALLA WALLA, WASHINGTON

**ICE HARBOR LOCK & DAM**  
SNAKE RIVER, OREGON, WASHINGTON & IDAHO

## SPILLWAY DEFLECTORS

OPTIONAL DEWATERING METHOD  
PIER WALL BRACKET - SECTIONS & DETAILS

SCALE AS SHOWN	INV. NO.
SHEET NO.	P.L. NO.



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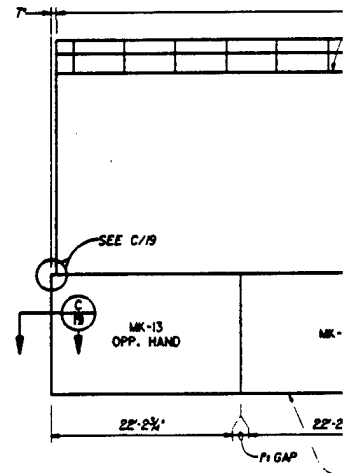
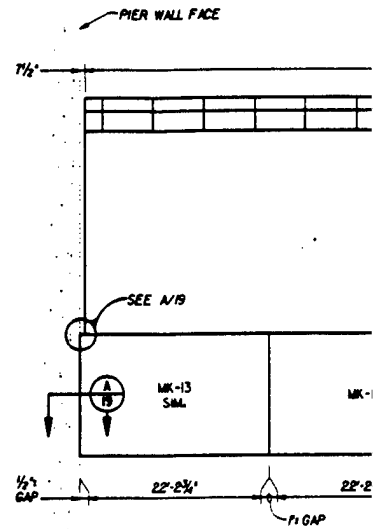
BULKHEAD  
SUPPORT  
FRAME

EL. 338.0

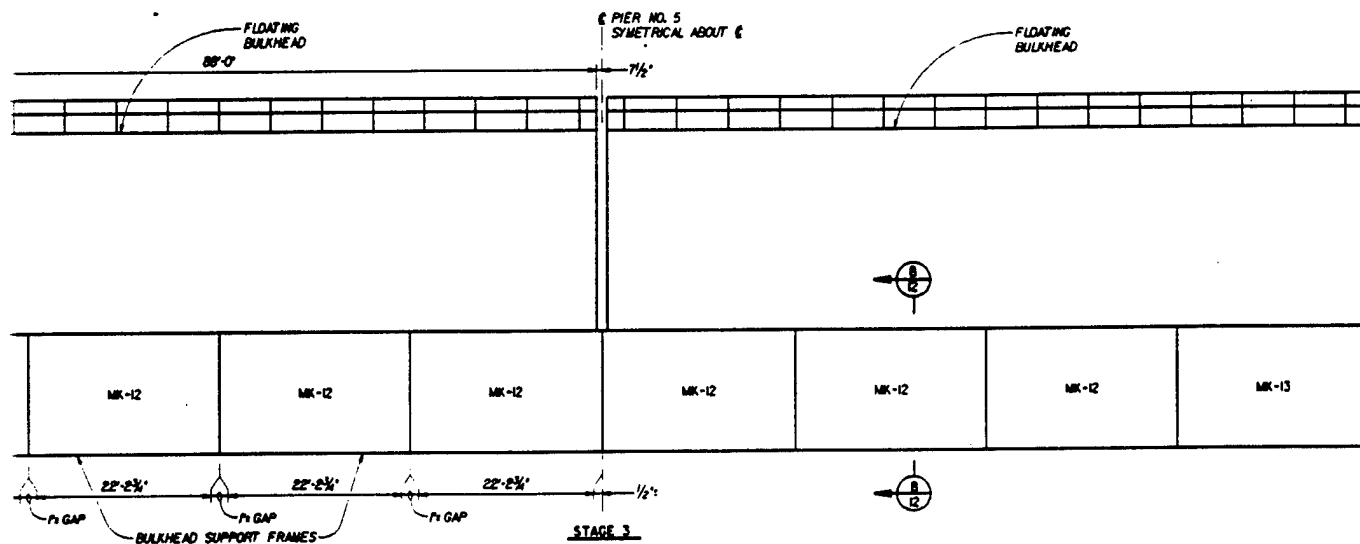
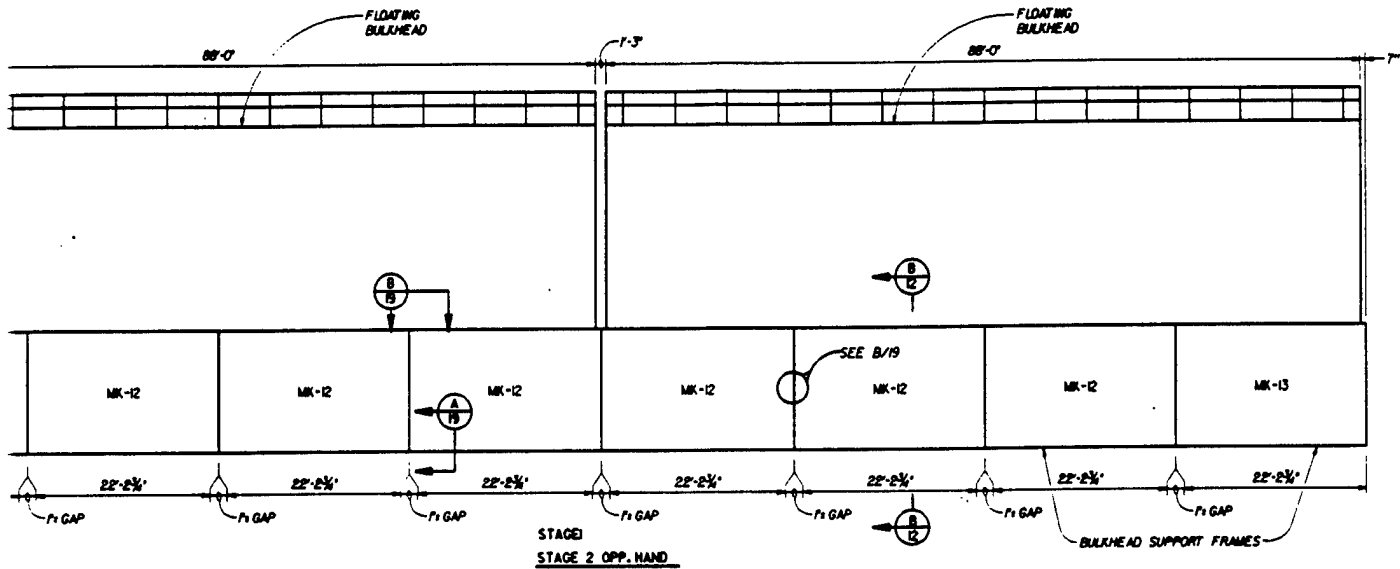
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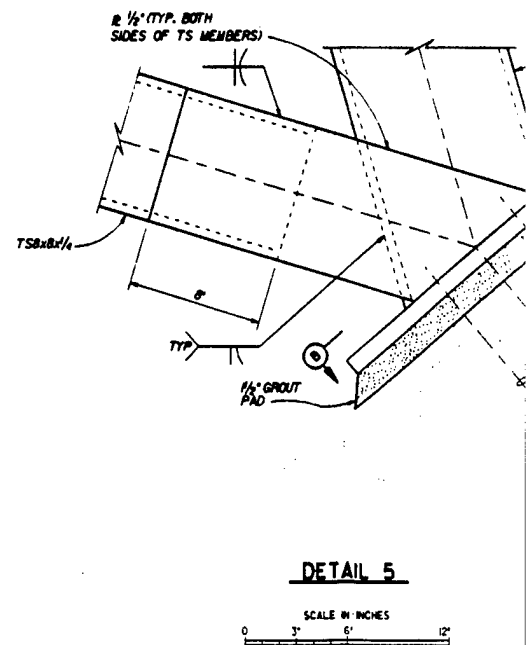
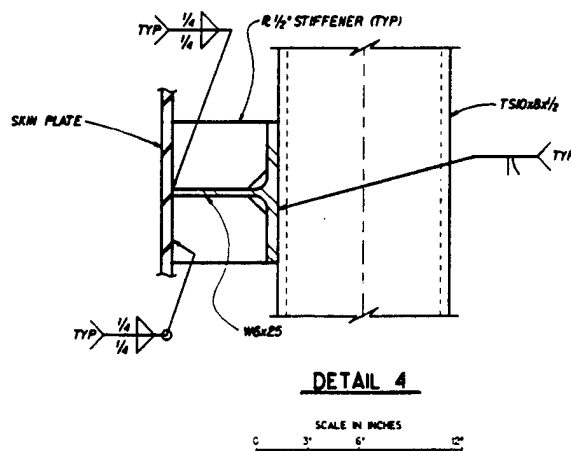
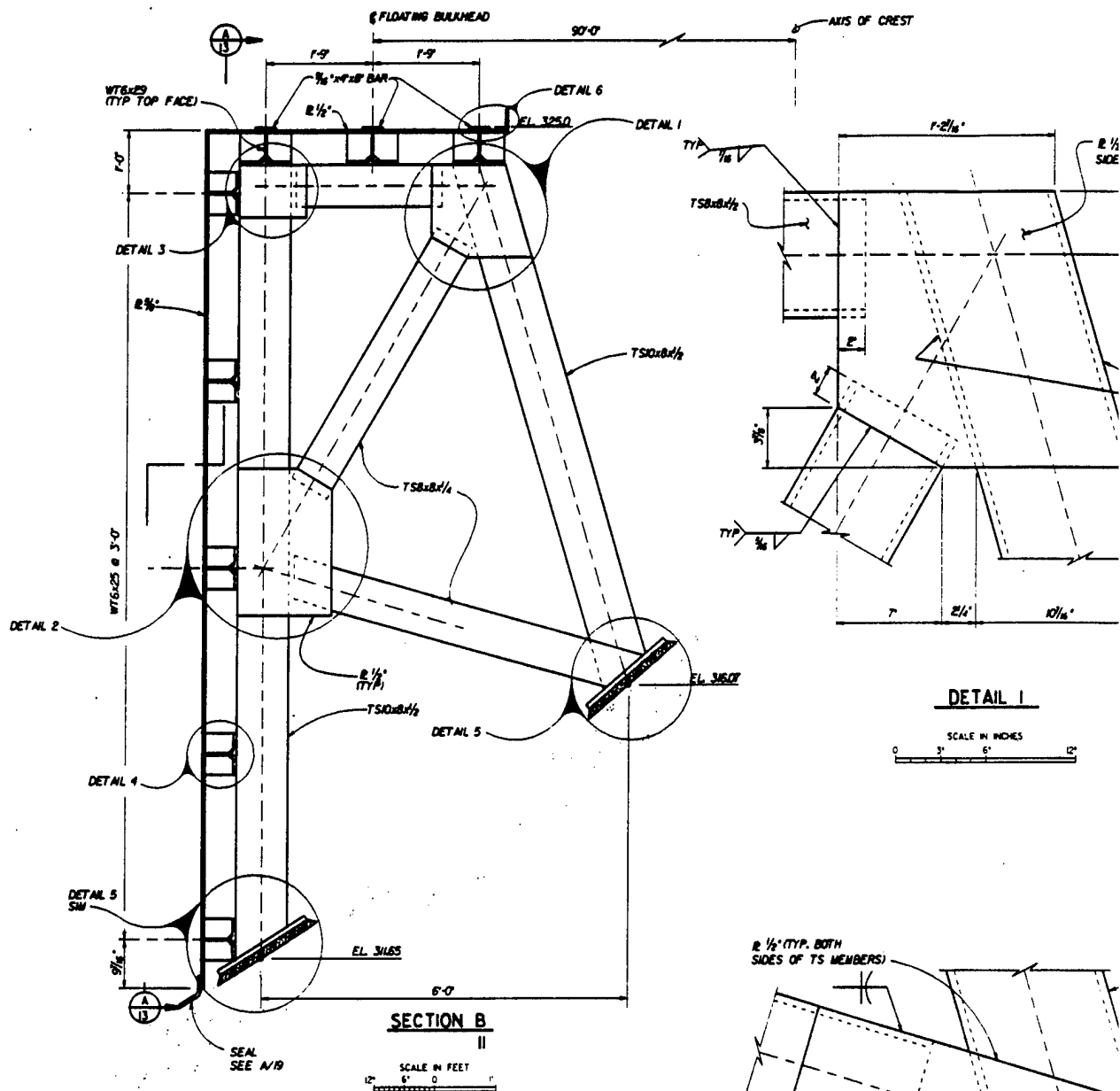
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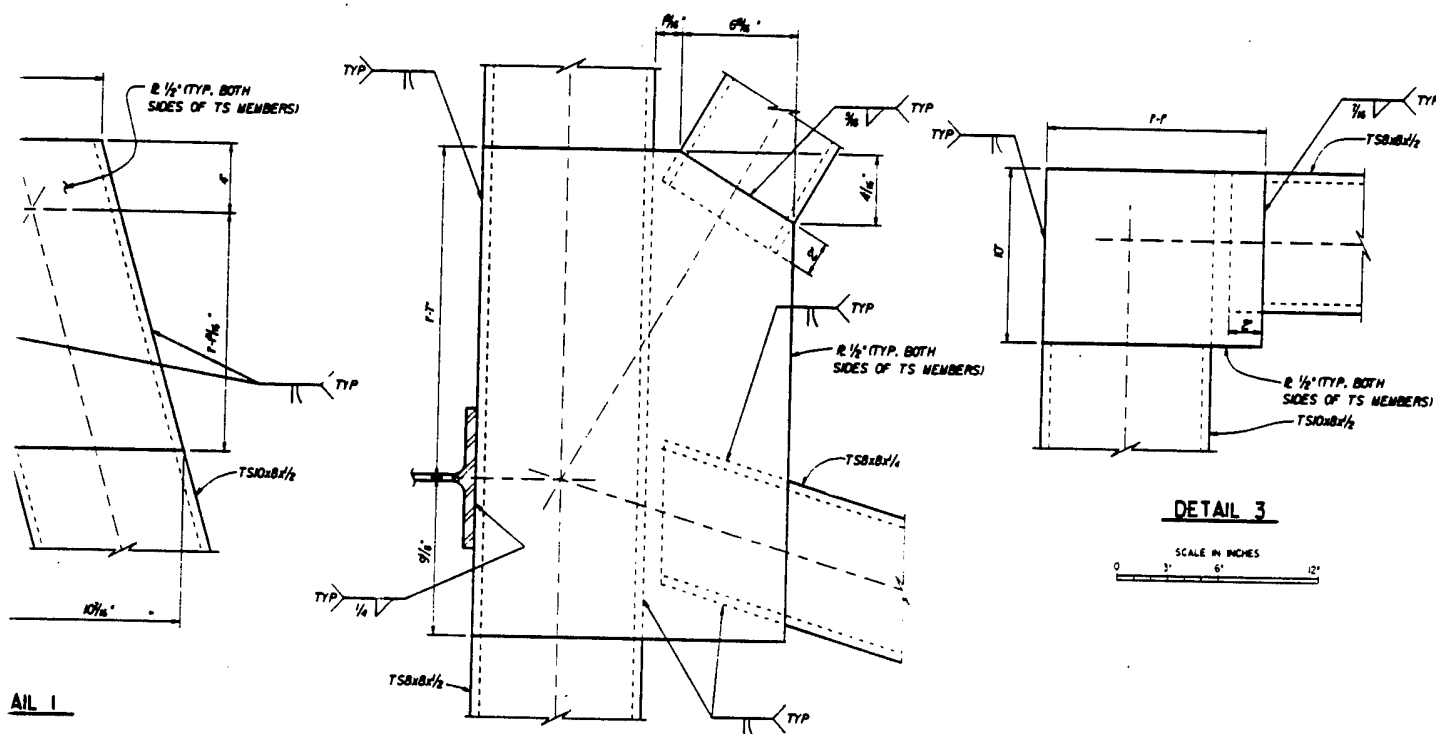
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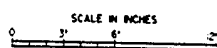
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DRAFTING

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ICE HARBOR LOCK & DAM SHAKE RIVER, OREGON, WASHINGTON & IDAHO				
SPILLWAY DEFLECTORS				
BULKHEAD SUPPORT FRAME SECTIONS & DETAILS I				
DESIGNED BY G. BUCKINGHAM		DATE		
CHECKED BY GLASSLEY		DATE		
APPROVED BY J. C. CROOK		DATE		
SUBMITTER		DATE		
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SHEET NO.		FILE NO.		

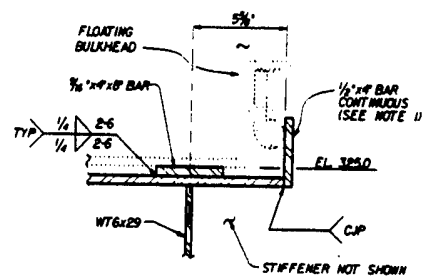
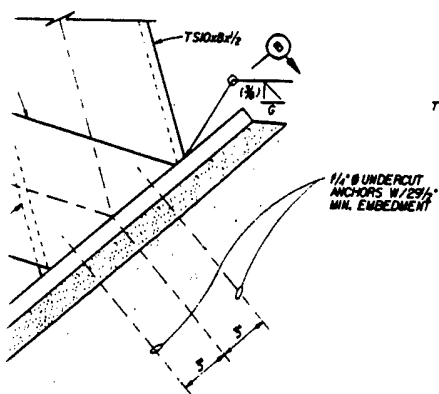
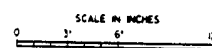




DETAIL 2



DETAIL 3



## NOTES:

1. TERMINATE BAR AS NEEDED TO AVOID INTERFERENCE WITH CENTER BRACE, END WALL FRAME AND PIER WALL BRACKET.

## LEGEND

EXISTING STRUCTURE  
NEW STRUCTURE

COMPUTER  
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DESIGN &  
DRAFTING

VALUE ENGINEERING PAYS

TACHED

\* INDICATES REFERENCE FILE DISPLAYED

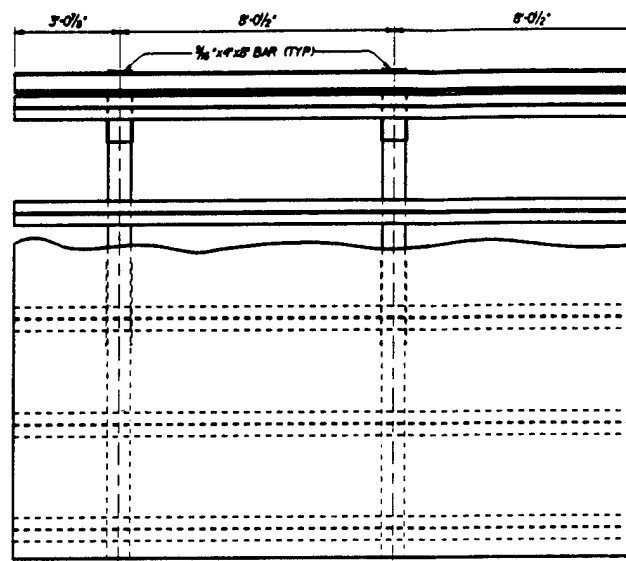
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MSD.BLK\*

LEVELS ON FOR CONTRACT DRWS

SCALE

PLATE 12

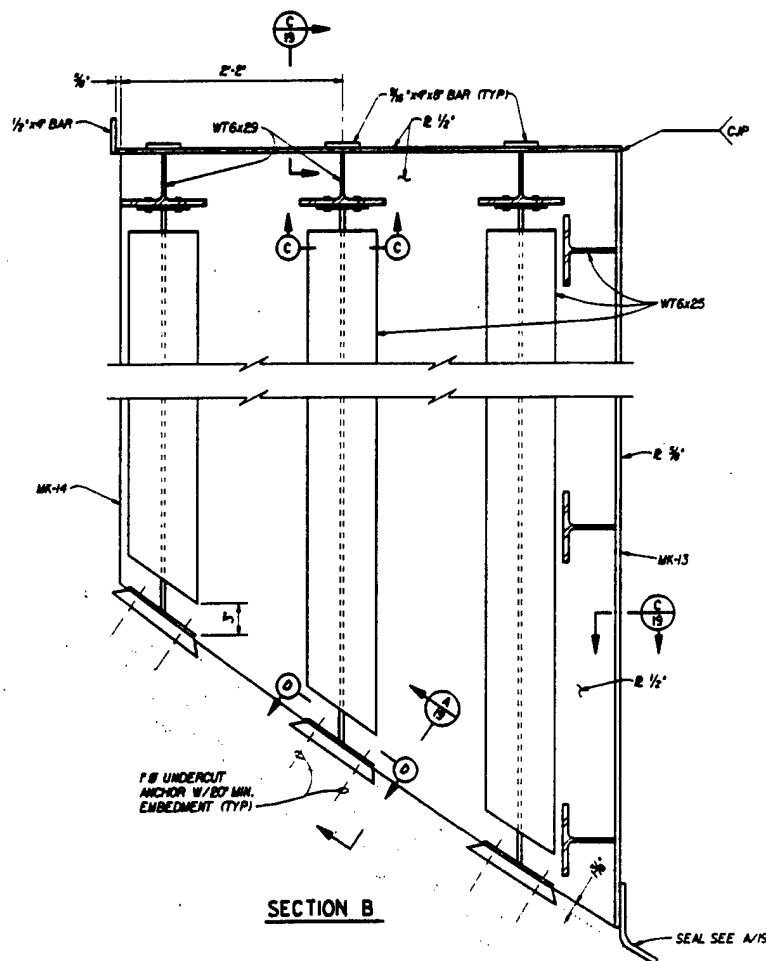
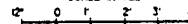
U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
G. BUCKINGHAM DESIGNED BY	ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO
GLASSLEY CHECKED BY	SPILLWAY DEFLECTORS
M. J. J. J. APPROVED BY	BULKHEAD SUPPORT FRAME SECTIONS & DETAILS 1
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FILE NO.	FILE NO.



UK-13

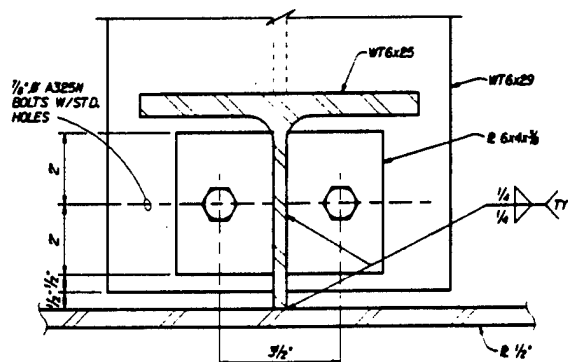
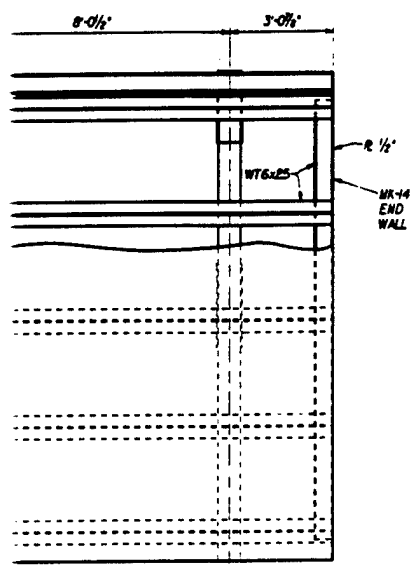
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SCALE IN FEET



## SECTION B

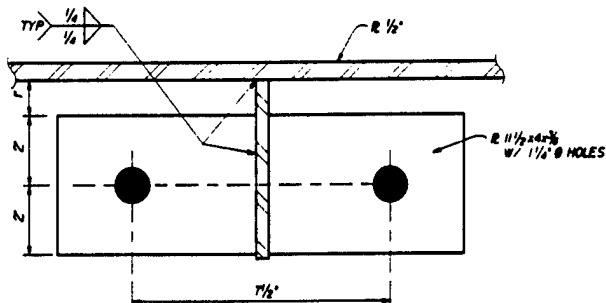
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SECTION C

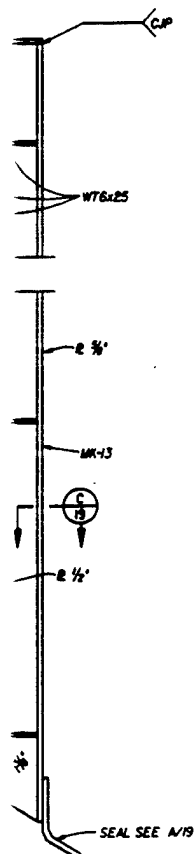
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SECTION D  
13 & 14

SCALE IN INCHES

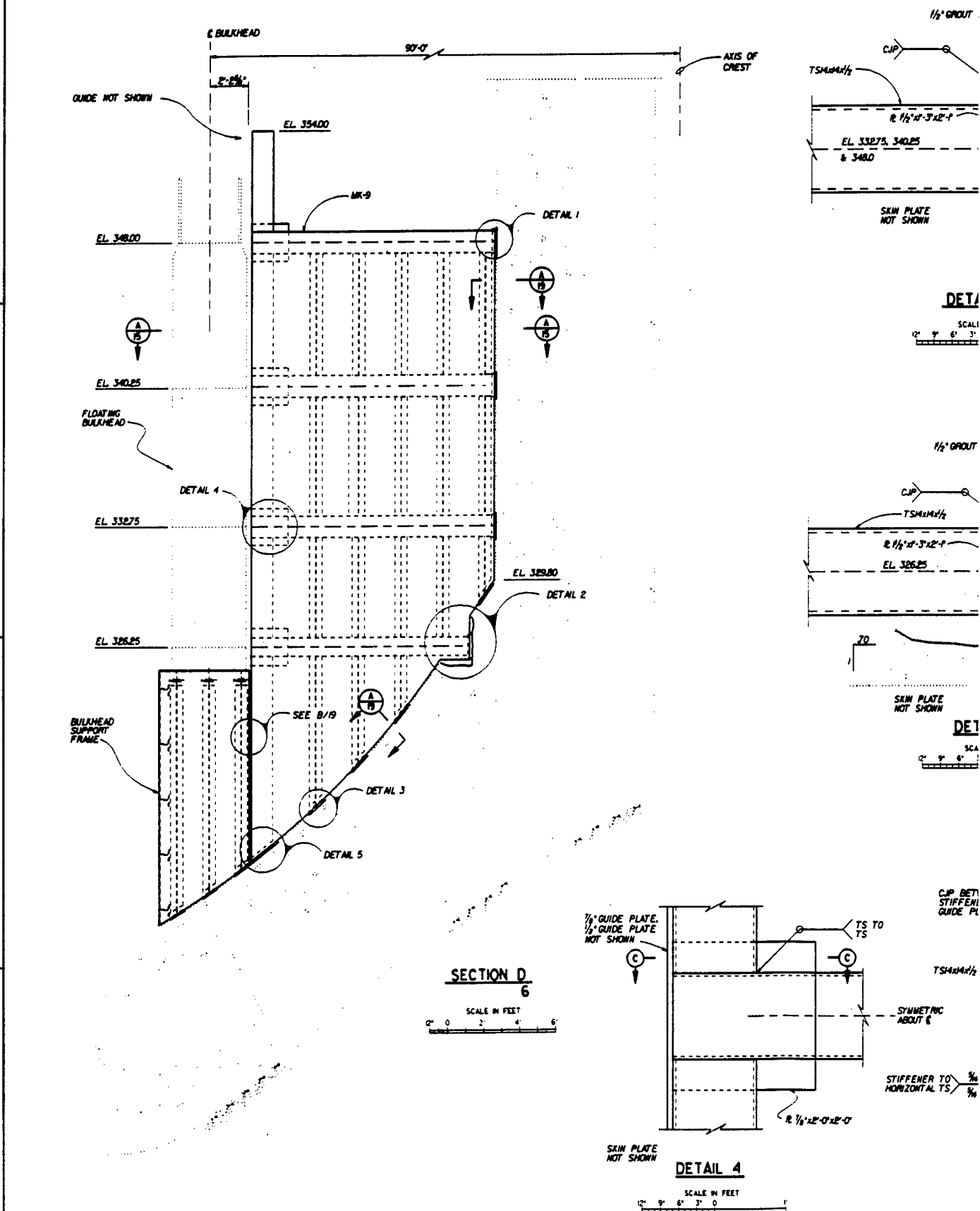
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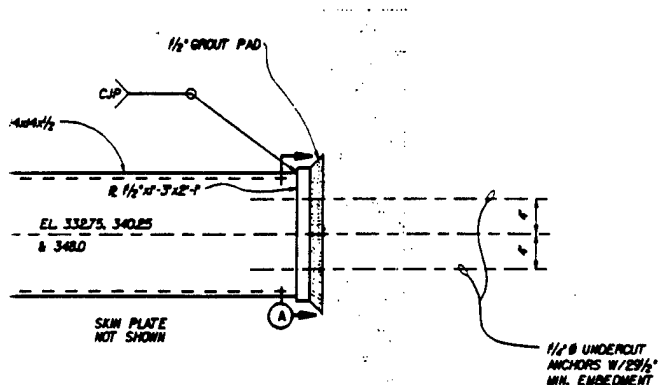


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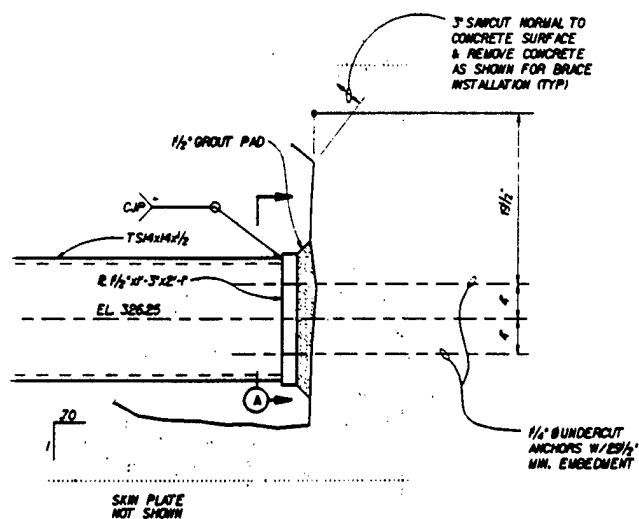
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ICE HARBOR LOCK & DAM SHAKE RIVER, OREGON, WASHINGTON & IDAHO SPILLWAY DEFLECTORS BULKHEAD SUPPORT FRAME SECTIONS & DETAILS III	
DESIGNED BY J. GLASSLEY	CHECKED BY J. GLASSLEY
DATE 10/1/88	DATE 10/1/88
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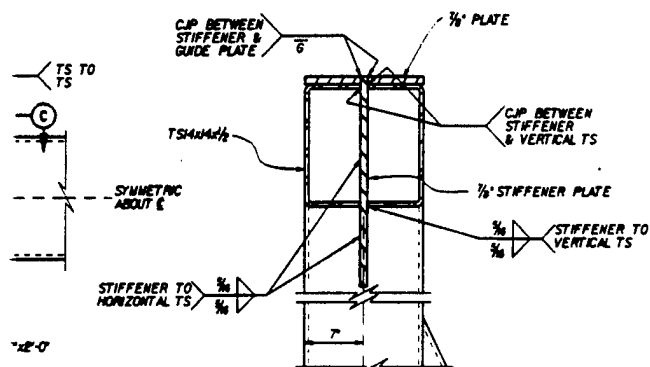
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SCALE IN FEET



DETAIL 2

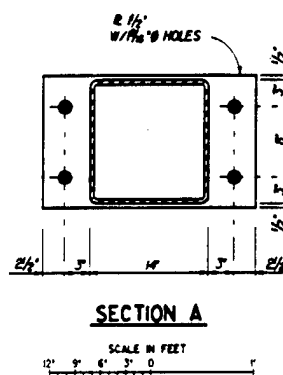
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SECTION C

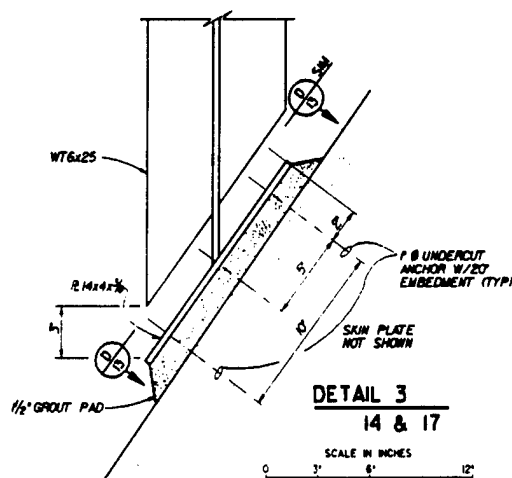
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NEW STRUCTURE

SECTION A

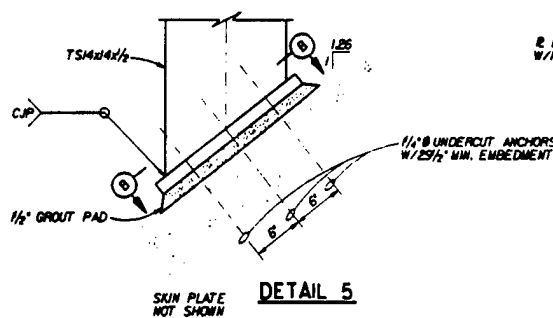
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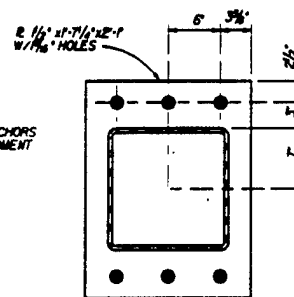
14 &amp; 17

SCALE IN INCHES



DETAIL 5

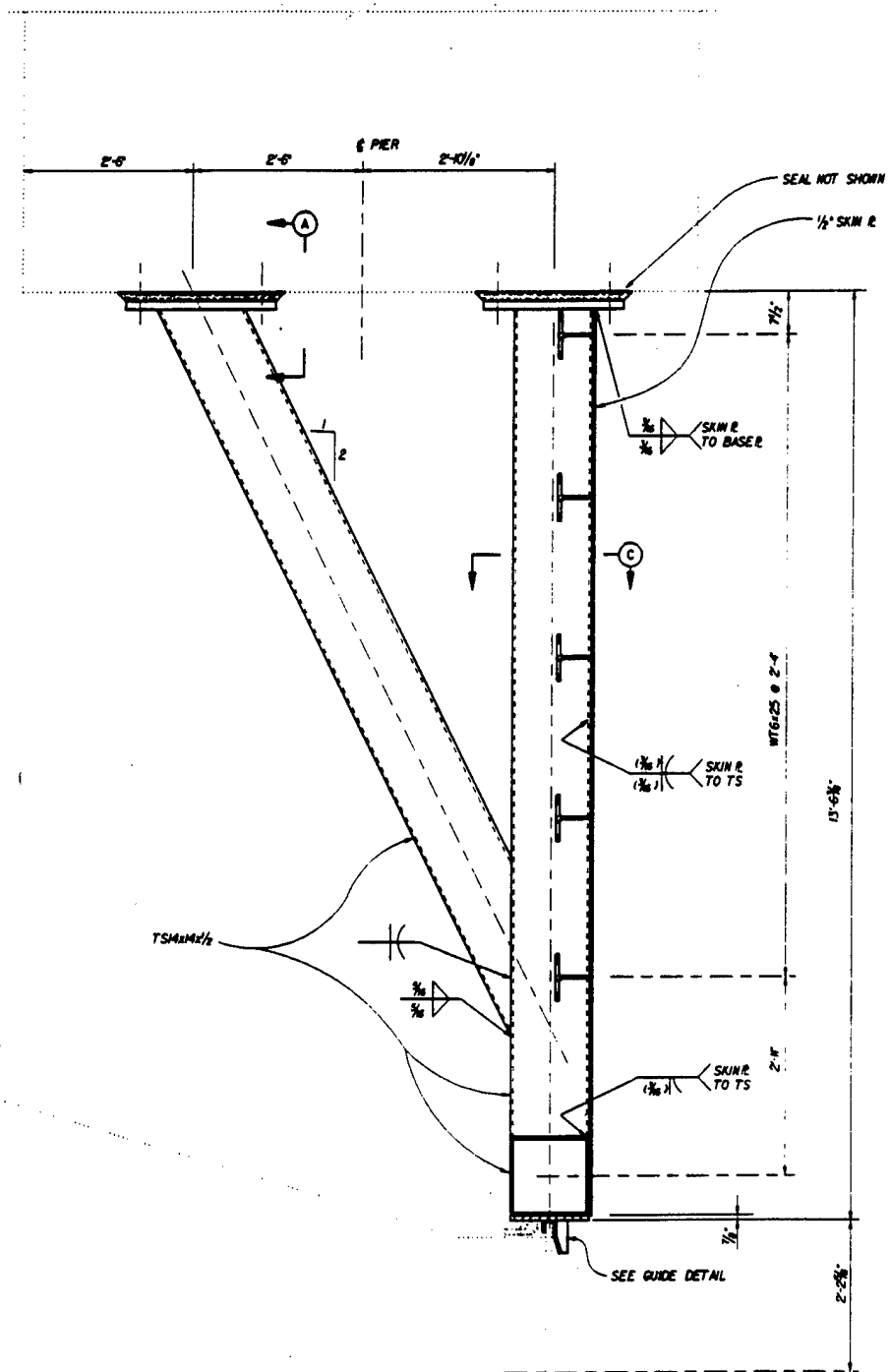
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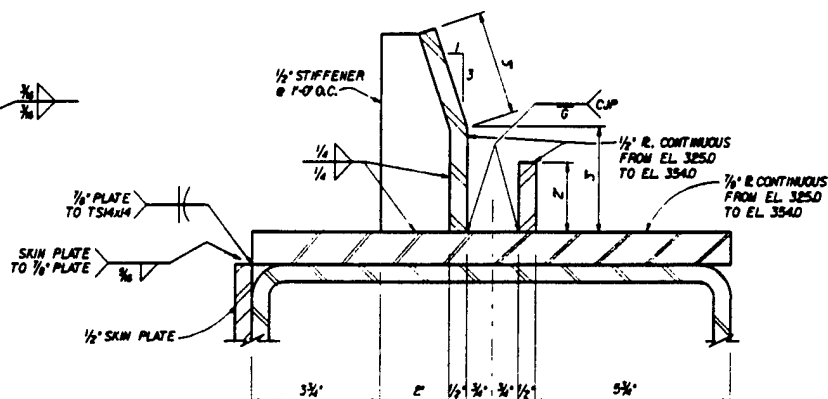
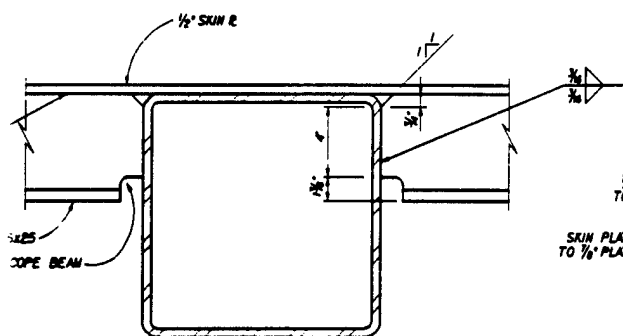
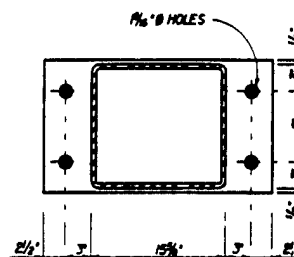
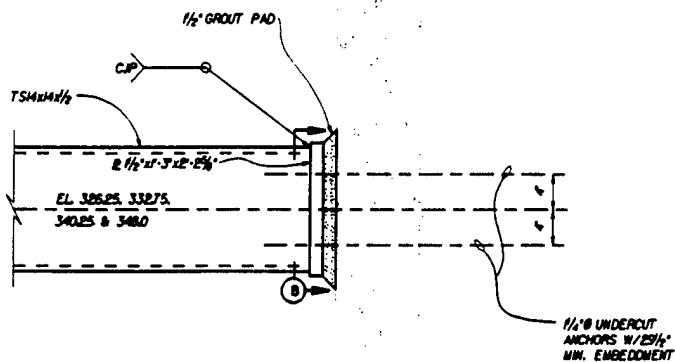
SECTION B

SCALE IN FEET

U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO SPILLWAY DEFLECTORS ENDWALL FRAME I SECTIONS & DETAILS I	
DESIGNED BY	DATE
CHECKED BY	DATE
APPROVED BY	DATE
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SHEET NO.	FILE NO.

SECTION A  
14SCALE IN FEET  
6" = 1'

①

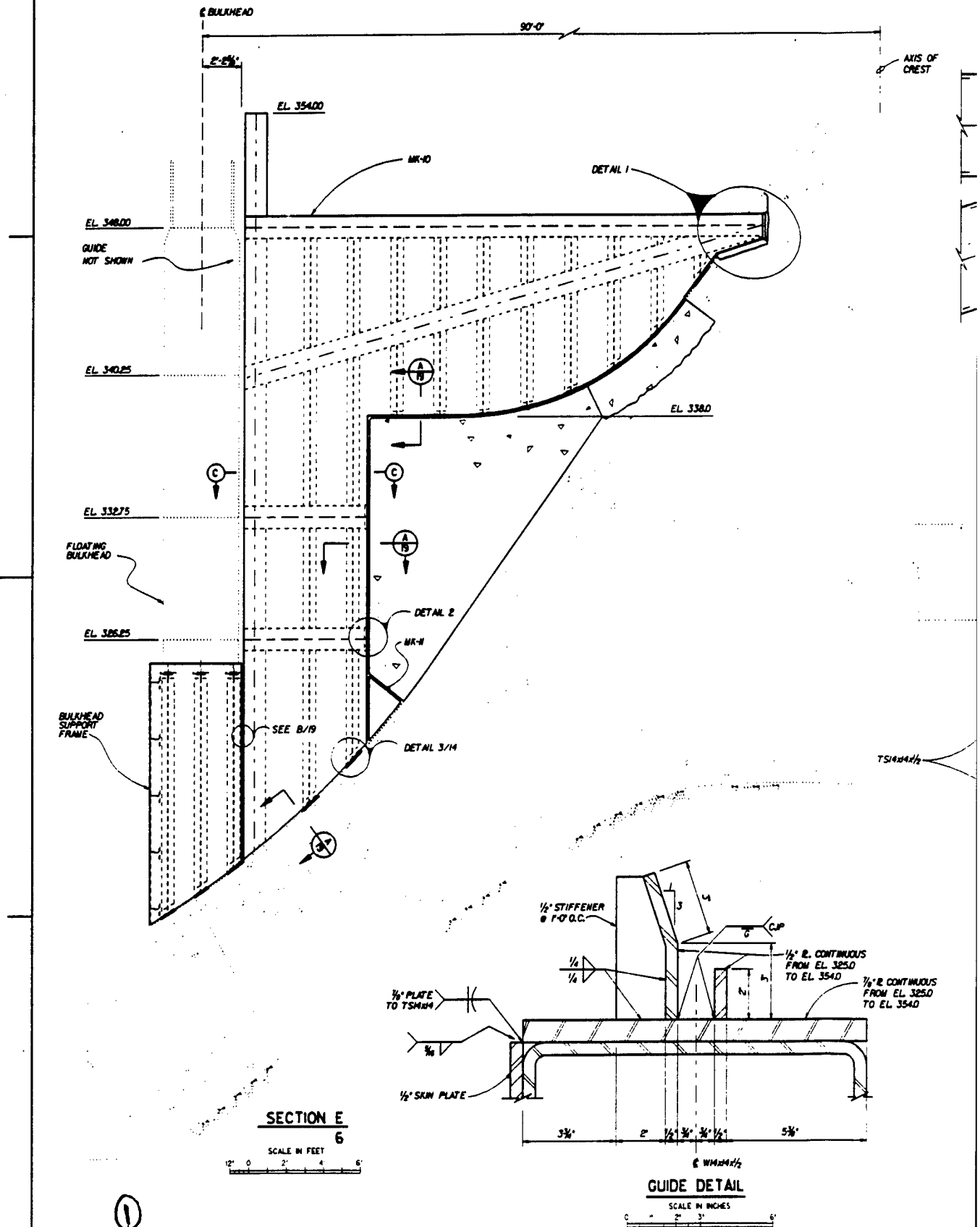


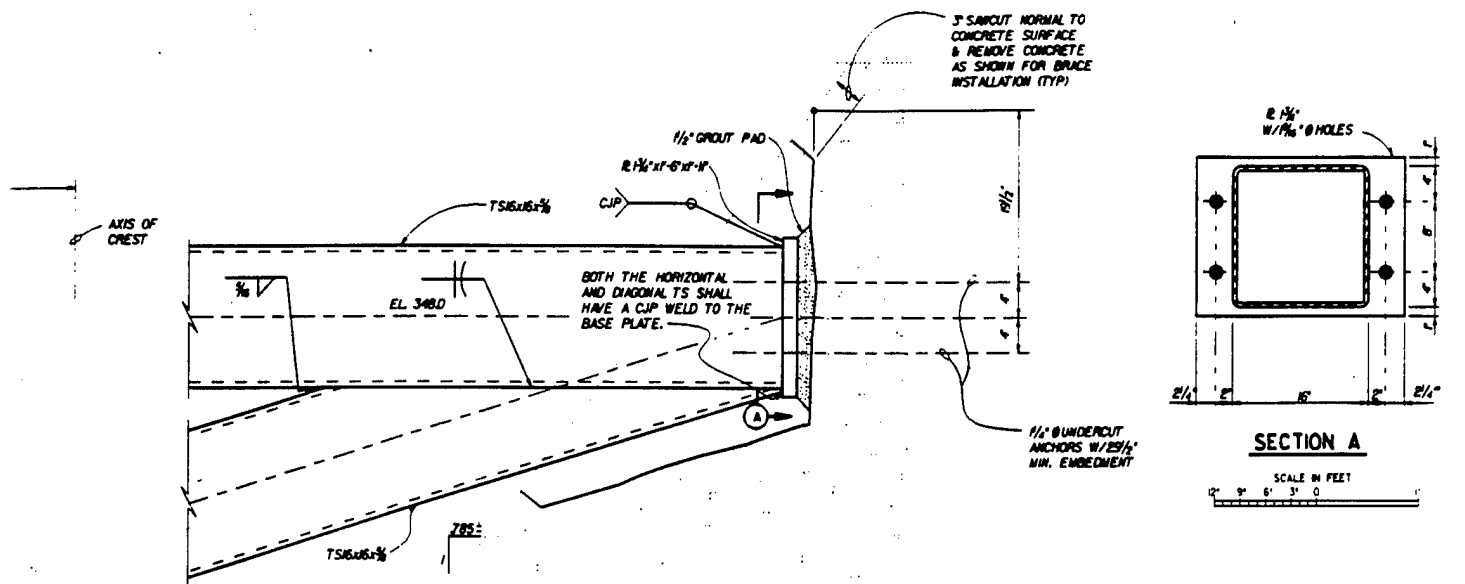
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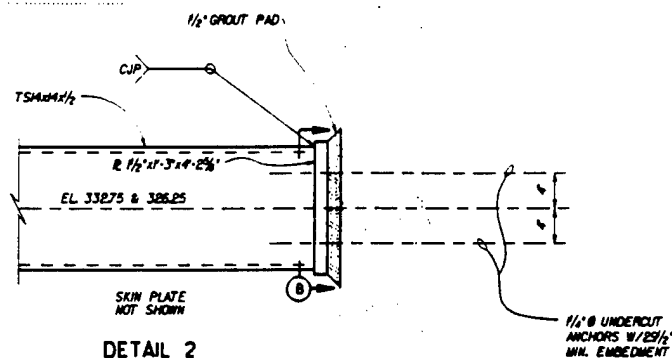


U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO	
SPILLWAY DEFLECTORS	
ENDWALL FRAME I SECTIONS & DETAILS II	
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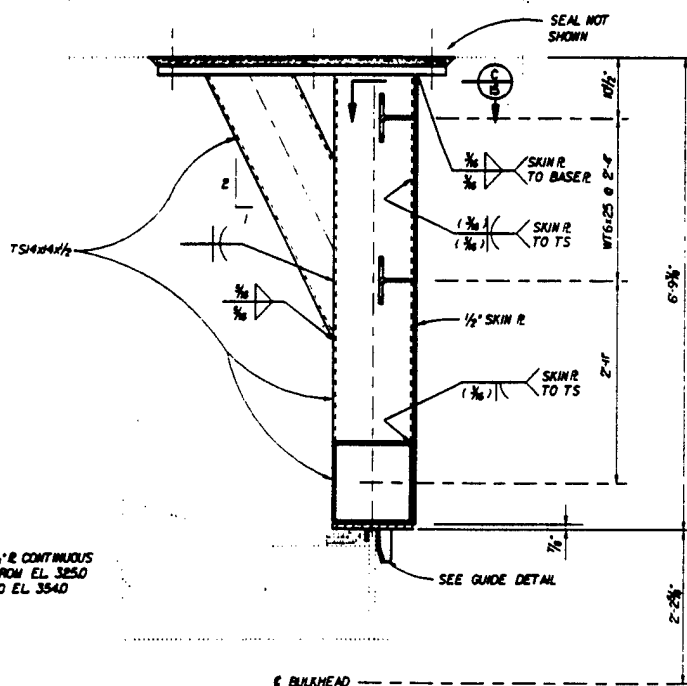




DETAIL 1

SCALE IN FEET  
12' 9' 6' 3' 0'

DETAIL 2

SCALE IN FEET  
12' 9' 6' 3' 0'

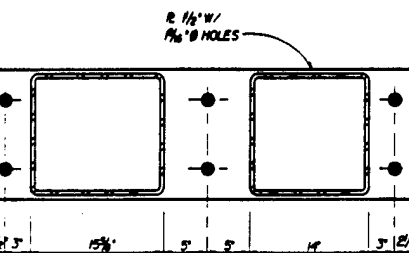
SECTION C

SCALE IN FEET  
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## LEGEND

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 --- NEW STRUCTURE

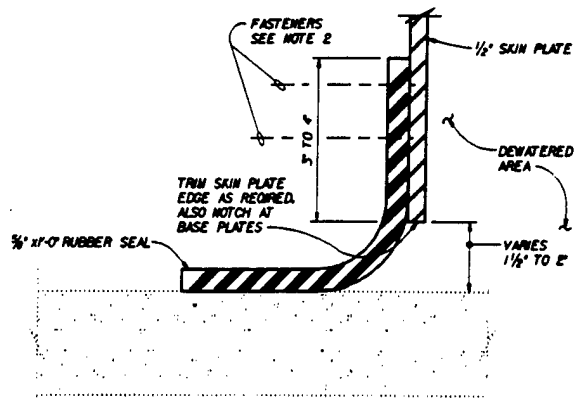
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DESIGN &  
DRAFTING



SECTION B

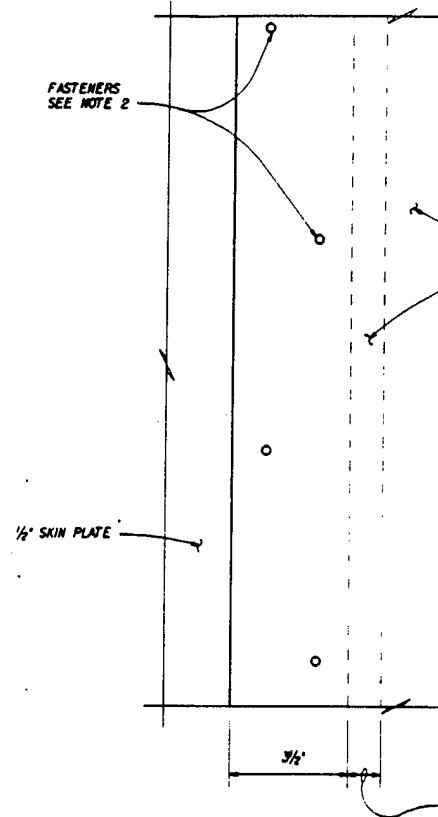
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REVISION		DATE	DESCRIPTION	CAD	APP
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ICE HARBOR LOCK & DAM SHARKE RIVER, OREGON, WASHINGTON & IDAHO SPILLWAY DEFLECTORS					
ENDWALL FRAME II SECTIONS & DETAILS I					
SUMMERS DESIGNED BY		DATE			
GLASSLEY CHECKED BY		DATE			
J. N. DESIGNED BY		DATE			
C. J. CHECKED BY		DATE			
SUBMITTED		DATE			
APPROVED		DATE			
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SHEET NO.		PL. NO.			



**SECTION A (TYP)**  
11, 12, 13, 14, & 17

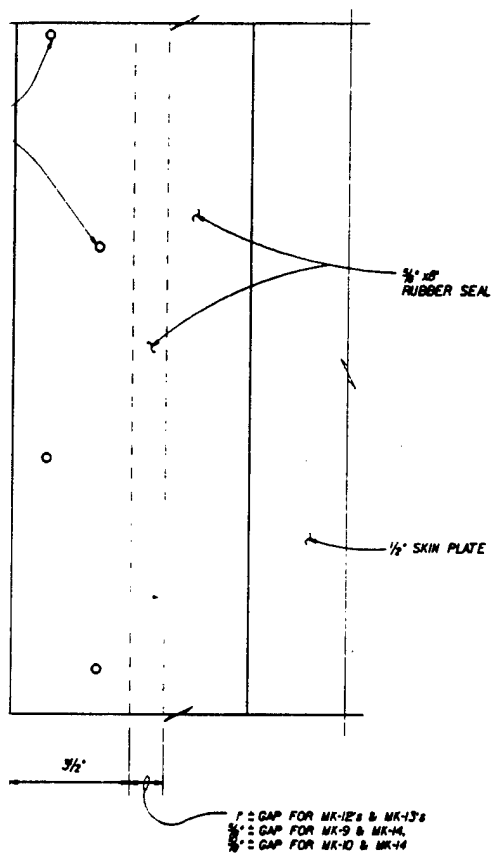
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**SECTION B**  
11, 12

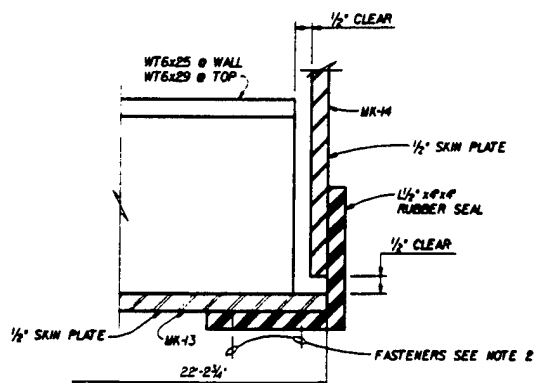
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**SECTION B (TYP)**  
11, 14, & 17

SCALE IN INCHES  
0 1 2 3 4 5



**SECTION C**  
11, & 13

SCALE IN INCHES  
0 1 2 3 4 5

## NOTES:

1. SEAL DETAILS ARE NOT SHOWN AT INTERSECTIONS WITH OTHER SEALS, WITH THE FLOATING BULKHEADS, OR BASE PLATES. IT IS THE CONTRACTORS RESPONSIBILITY TO PROVIDE DETAILING AND SEALS AS REQUIRED TO CONTROL LEAKAGE.
2. TYPE, SIZE AND SPACING OR METHOD OF FASTENING SEALS IS THE CONTRACTORS RESPONSIBILITY. SYSTEMS INCLUDE ADHESIVES, SCREWS, BOLTS OR POWER DRIVEN FASTENERS.

## **APPENDIX A**

### **Hydrologic Information**

## APPENDIX A

### HYDROLOGIC INFORMATION

Table 1	Columbia River - Computed Surface Elevations at River Mile 324.2
Table 2	Snake River - Computed Surface Elevations at River Mile 9.23
Table 3	Snake River - Computed Surface Elevations at River Mile 9.42
Chart 1	Columbia River - Discharge Rating Curves at River Mile 324.2
Chart 2	Snake River - Discharge Rating Curves at River Mile 9.23
Chart 3	Snake River - Discharge Rating Curves at River Mile 9.23
Chart 4	Snake River - Discharge Rating Curves at River Mile 9.42
Chart 5	Snake River - Discharge Rating Curves at River Mile 9.42
Chart 6	Annual Peak Discharge Frequencies - Snake River at Lower Granite Dam
Chart 7	Summary Hydrographs - Snake River near Clarkston, Washington

8 May 1995

MEMORANDUM THRU

Chief, Planning Division

Chief, Engineering Division

Chief, Design Branch

FOR Chief, Hydraulic Design Section,  
ATTN: Jim Cain

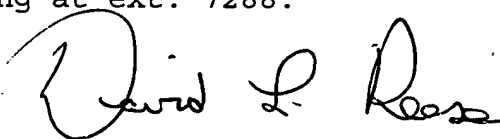
SUBJECT: Ice Harbor Dam Model Studies: Discharge Rating Curves  
at Columbia River Mile 324.2 and Snake River Miles 9.23 and 9.42

1. Discharge rating curves and tables are enclosed for the Columbia River at the Snake River confluence and at two locations on the Snake River below Ice Harbor Dam. The charts and tables were prepared in accordance with your work request dated 20 January 1995. All of the curves were computed using the Hydrologic Engineering Center's computer program, "Water Surface Profiles" (HEC-2), version 4.6.2.
2. Chart 1 displays the discharge rating curves for the Columbia River at the confluence with the Snake River (Columbia River mile 324.2). These curves were computed using a calibrated HEC-2 model of McNary Reservoir. The cross section geometry for the model is based on sedimentation range surveys completed in 1986. The model calibrations were performed using measured water surface profiles at flows up to 300,000 cubic feet per second (cfs). The computed average elevation error in that range of flows is about 0.5 feet. For flows up to the maximum of 1,400,000 cfs shown on the graph, the average elevation error increases to about 0.8 feet.
3. Charts 2 and 3 display the discharge rating curves for the Snake River mile 9.23 location. Charts 4 and 5 are similar curves for the Snake River mile 9.42 location. The river mile locations are about 2,000 feet and 1,000 feet, respectively, downstream of the Ice Harbor Dam powerhouse tailrace deck.
4. The curves shown on Charts 2 through 5 were computed using a calibrated model of the lower Snake River. The channel geometry for cross sections from the confluence upstream to river mile 6.79 is based on 1978 sedimentation range surveys. The channel geometry for sections from river mile 7.17 to 9.16 is taken from sounding maps produced from 1981 field surveys. The portions of the channel sections in the navigation channel upstream to river

mile 9.16 were checked against construction templates for the 1979 and 1985 navigation channel improvement contracts. The channel sections from river mile 9.23 upstream to Ice Harbor Dam were taken from sounding maps produced from 1994 field surveys. All Snake River overbank sections were extended using topographic maps with 10-foot contours. The maps were produced from 1956 and 1957 aerial photography. The HEC-2 model of the lower Snake River was then calibrated using Ice Harbor Dam tailwater data for flows up to 169,000 cfs. The computed average elevation error of the discharge rating curves in that range of flows is about 0.3 feet. For higher flows up to the Spillway Design Flood of 850,000 cfs, the computed average elevation error increases to about 0.7 feet.

5. Table 1 presents the discharge and elevation values used to construct the rating curves for Columbia River mile 324.2 (Chart 1). Tables 2 and 3 present the equivalent data for the rating curves at Snake River miles 9.23 and 9.42, respectively (Charts 2 through 5).

6. If you have questions concerning the curves or the tables, please call Mr. Steve Spaulding at ext. 7288.



DAVID L. REESE  
Chief, Hydrology Branch

8 Encls

CF w/encls:  
CENPW-PL-H (Ed Kim)

### NOTES:

1. Columbia River mile 324.2 is located at the confluence of the Snake and Columbia rivers on McNary Reservoir near Pasco and Kennewick, Washington.
2. Water surface elevations were computed using the Hydrologic Engineering Center's computer program HEC-2 version 4.6.2. The cross sectional data for the HEC-2 model was obtained from sedimentation range surveys conducted in 1986.
3. The HEC-2 model was calibrated using actual flow data and measured water surface profiles along the entire reach of the McNary pool. Discharges used in the calibrations range up to 300,000 cfs. The average elevation error of the computed water surface elevations in that range is about 0.5 feet. At flows up to 1,400,000 cfs, the average estimated error increases to about 0.8 feet, although the maximum reasonable error could be about 1.8 feet.
4. Each column represents computed water surface elevations for a range of discharges and a specific forebay elevation at McNary Dam, located at river mile 292.0. The river discharge applies to the entire reach from the dam upstream to the Snake River confluence.
5. Source for spillway capacities with freeflow conditions: Table 3-3, McNary Water Control Manual dated August, 1989.

COMPUTED WATER SURFACE ELEVATIONS AT RM 324.2 IN FEET MSL			
DISCHARGE IN CUBIC FEET PER SECOND	WITH McNARY DAM FOREBAY ELEVATION AT 335 MSL	WITH McNARY DAM FOREBAY ELEVATION AT 337 MSL	WITH McNARY DAM FOREBAY ELEVATION AT 340 MSL
0	335.0	337.0	340.0
50,000	335.0	337.0	340.0
100,000	335.2	337.1	340.1
150,000	335.4	337.3	340.2
200,000	335.7	337.5	340.4
250,000	336.0	337.8	340.6
300,000	336.4	338.2	340.8
400,000	337.4	339.0	341.4
500,000	338.6	339.9	342.1
600,000	339.7	340.9	342.9
800,000	342.0	342.9	344.6
1,000,000	344.3	345.0	346.4
1,200,000		347.0	348.2

CONFLUENCE ELEVATIONS AT McNARY SPILLWAY CAPACITY			
McNARY DAM FOREBAY ELEVATION IN FEET MSL	335	337	340
SPILLWAY CAPACITY IN CUBIC FEET PER SECOND	1,150,000	1,235,000	1,365,000
ELEVATION AT CONFLUENCE WITH SNAKE RIVER	345.9	347.4	349.7

COLUMBIA RIVER BASIN, WASHINGTON

### COMPUTED WATER SURFACE ELEVATIONS AT RIVER MILE 324.2

U. S. ARMY ENGINEER DISTRICT  
WALLA WALLA - HYDROLOGY BRANCH

A00323.PPP

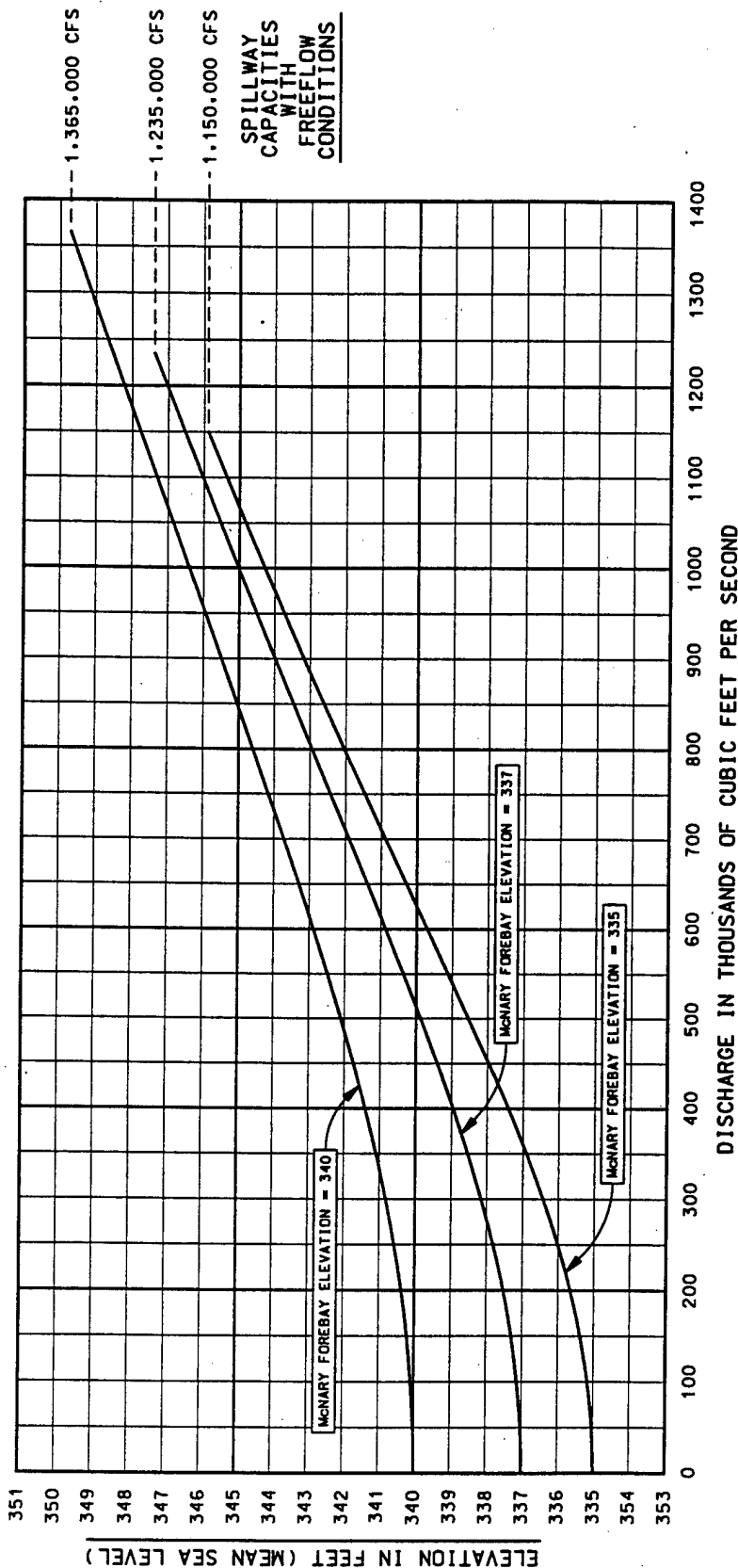
DESIGNED  
SPAULDING

DRAWN  
SCHUSTER

DATE  
APR 1995

DISCHARGE IN CFS	CONFLUENCE ELEVATION IN FEET ABOVE MEAN SEA LEVEL										
	335	337	339	340	342	344	346	348	350	352	
0	335.0	337.0	339.0	340.0	342.0	344.0	346.0	348.0	350.0	352.0	
5,000	335.2	337.1	339.1	340.0	342.0	344.0	346.0	348.0	350.0	352.0	
10,000	335.7	337.4	339.2	340.1	342.1	344.1	346.0	348.0	350.0	352.0	
15,000	336.3	337.7	339.4	340.3	342.2	344.1	346.1	348.1	350.0	352.0	
20,000	337.1	338.2	339.7	340.5	342.3	344.2	346.1	348.1	350.1	352.1	
25,000	337.8	338.7	340.0	340.8	342.5	344.3	346.2	348.1	350.1	352.1	
30,000	338.5	339.3	340.4	341.1	342.7	344.5	346.3	348.2	350.2	352.1	
35,000	339.2	339.8	340.8	341.4	342.9	344.6	346.4	348.3	350.2	352.1	
40,000	339.8	340.3	341.2	341.8	343.2	344.8	346.5	348.4	350.3	352.2	
45,000	340.3	340.8	341.8	342.3	343.6	345.1	346.8	348.6	350.5	352.4	
50,000	340.9	341.4	342.5	343.3	344.3	345.6	347.1	348.8	350.6	352.4	
55,000	341.5	342.1	343.2	344.0	345.5	346.6	347.8	349.3	351.0	352.7	
60,000	342.0	342.7	343.8	344.6	346.7	347.6	348.7	350.0	351.5	353.1	
65,000	342.5	343.2	344.3	345.1	347.2	348.1	349.2	350.7	352.0	353.5	
70,000	343.0	343.7	344.8	345.6	347.7	348.6	349.5	351.4	352.6	354.0	
75,000	343.5	344.2	345.3	346.1	348.2	349.1	350.4	351.4	352.6	354.0	
80,000	344.0	344.7	345.8	346.6	348.7	349.6	350.9	351.9	353.0	354.5	
85,000	344.5	345.2	346.3	347.1	349.2	350.1	351.4	352.2	353.3	354.5	
90,000	345.0	345.7	346.8	347.6	349.7	350.6	351.9	352.7	353.9	355.1	
95,000	345.5	346.2	347.3	348.1	350.2	351.1	352.4	353.0	354.6	355.7	
100,000	346.0	346.7	347.8	348.6	350.7	351.6	352.9	353.7	354.6	355.7	
105,000	346.5	347.2	348.3	349.1	351.2	352.1	353.4	354.2	355.7	357.2	
110,000	347.0	347.7	348.8	349.6	351.7	352.6	353.9	354.7	356.3	357.2	
115,000	347.5	348.2	349.3	350.1	352.2	353.1	354.4	355.2	356.3	357.2	
120,000	348.0	348.7	349.8	350.6	352.7	353.6	354.9	355.7	356.3	357.2	
125,000	348.5	349.2	350.3	351.1	353.2	354.1	355.4	356.2	357.5	358.7	
130,000	349.0	349.7	350.8	351.6	353.7	354.6	355.9	356.7	357.5	358.7	
135,000	349.5	350.2	351.3	352.1	354.2	355.1	356.4	357.2	358.1	359.7	
140,000	350.0	350.7	351.8	352.6	354.7	355.6	356.9	357.7	358.5	360.3	
145,000	350.5	351.2	352.3	353.1	355.2	356.1	357.4	358.2	359.0	361.8	
150,000	351.0	351.7	352.8	353.6	355.7	356.6	357.9	358.7	359.5	361.4	
155,000	351.5	352.2	353.3	354.1	356.2	357.1	358.4	359.2	360.0	362.8	
160,000	352.0	352.7	353.8	354.6	356.7	357.6	358.9	359.7	360.5	363.3	
165,000	352.5	353.2	354.3	355.1	357.2	358.1	359.4	360.2	361.0	363.8	
170,000	353.0	353.7	354.8	355.6	357.7	358.6	359.9	360.7	361.5	364.3	
175,000	353.5	354.2	355.3	356.1	358.2	359.1	360.4	361.2	362.0	364.8	
180,000	354.0	354.7	355.8	356.6	358.7	359.6	360.9	361.7	362.5	365.3	
185,000	354.5	355.2	356.3	357.1	359.2	360.1	361.4	362.2	363.0	365.8	
190,000	355.0	355.7	356.8	357.6	359.7	360.6	361.9	362.7	363.5	366.3	
195,000	355.5	356.2	357.3	358.1	360.2	361.1	362.4	363.2	364.0	366.5	
200,000	356.0	356.7	357.8	358.6	360.7	361.6	362.9	363.7	364.5	367.0	
205,000	356.5	357.2	358.3	359.1	361.2	362.1	363.4	364.2	365.0	367.5	
210,000	357.0	357.7	358.8	359.6	361.7	362.6	363.9	364.7	365.5	368.0	
215,000	357.5	358.2	359.3	360.1	362.2	363.1	364.4	365.2	366.0	368.5	
220,000	358.0	358.7	359.8	360.6	362.7	363.6	364.9	365.7	366.5	369.0	
225,000	358.5	359.2	360.3	361.1	363.2	364.1	365.4	366.2	367.0	370.0	
230,000	359.0	359.7	360.8	361.6	363.7	364.6	365.9	366.7	367.5	371.0	
235,000	359.5	360.2	361.3	362.1	364.2	365.1	366.4	367.2	368.0	371.5	
240,000	360.0	360.7	361.8	362.6	364.7	365.6	366.9	367.7	368.5	372.0	
245,000	360.5	361.2	362.3	363.1	365.2	366.1	367.4	368.2	369.0	372.5	
250,000	361.0	361.7	362.8	363.6	365.7	366.6	367.9	368.7	369.5	373.0	
255,000	361.5	362.2	363.3	364.1	366.2	367.1	368.4	369.2	370.0	373.5	
260,000	362.0	362.7	363.8	364.6	366.7	367.6	368.9	369.7	370.5	374.0	
265,000	362.5	363.2	364.3	365.1	367.2	368.1	369.4	370.2	371.0	374.5	
270,000	363.0	363.7	364.8	365.6	367.7	368.6	369.9	370.7	371.5	375.0	
275,000	363.5	364.2	365.3	366.1	368.2	369.1	370.4	371.2	372.0	375.5	
280,000	364.0	364.7	365.8	366.6	368.7	369.6	370.9	371.7	372.5	376.0	
285,000	364.5	365.2	366.3	367.1	369.2	370.1	371.4	372.2	373.0	376.5	
290,000	365.0	365.7	366.8	367.6	369.7	370.6	371.9	372.7	373.5	377.0	
295,000	365.5	366.2	367.3	368.1	370.2	371.1	372.4	373.2	374.0	377.5	
300,000	366.0	366.7	367.8	368.6	370.7	371.6	372.9	373.7	374.5	378.0	
305,000	366.5	367.2	368.3	369.1	371.2	372.1	373.4	374.2	375.0	378.5	
310,000	367.0	367.7	368.8	369.6	371.7	372.6	373.9	374.7	375.5	379.0	
315,000	367.5	368.2	369.3	370.1	372.2	373.1	374.4	375.2	376.0	379.5	
320,000	368.0	368.7	369.8	370.6	372.7	373.6	374.9	375.7	376.5	380.0	
325,000	368.5	369.2	370.3	371.1	373.2	374.1	375.4	376.2	377.0	380.5	
330,000	369.0	369.7	370.8	371.6	373.7	374.6	375.9	376.7	377.5	381.0	
335,000	369.5	370.2	371.3	372.1	374.2	375.1	376.4	377.2	378.0	381.5	
340,000	370.0	370.7	371.8	372.6	374.7	375.6	376.9	377.7	378.5	382.0	
345,000	370.5	371.2	372.3	373.1	375.2	376.1	377.4	378.2	379.0	382.5	
350,000	371.0	371.7	372.8	373.6	375.7	376.6	377.9	378.7	379.5	383.0	
355,000	371.5	372.2	373.3	374.1	376.2	377.1	378.4	379.2	380.0	383.5	
360,000	372.0	372.7	373.8	374.6	376.7	377.6	378.9	379.7	380.5	384.0	
365,000	372.5	373.2	374.3	375.1	377.2	378.1	379.4	380.2	381.0	384.5	
370,000	373.0	373.7	374.8	375.6	377.7	378.6	379.9	380.7	381.5	385.0	
375,000	373.5	374.2	375.3	376.1	378.2	379.1	380.4	381.2	382.0	385.5	
380,000	374.0	374.7	375.8	376.6	378.7	379.6	380.9	381.7	382.5	386.0	
385,000	374.5	375.2	376.3	377.1	379.2	380.1	381.4	382.2	383.0	386.5	
390,000	375.0	375.7	376.8	377.6	379.7	380.6	381.9	382.7	383.5	387.0	
395,000	375.5	376.2	377.3	378.1	380.2	381.1	382.4	383.2	384.0	387.5	
400,000	376.0	376.7	377.8	378.6	380.7	381.6	382.9	383.7	384.5	388.0	
405,000	376.5	377.2	378.3	379.1	381.2	382.1	383.4	384.2	385.0	388.5	
410,000	377.0	377.7	378.8	379.6	381.7	382.6	383.9	384.7	385.5	389.0	
415,000	377.5	378.2	379.3	380.1	382.2	383.1	384.4	385.2	386.0	389.5	
420,000	378.0	378.7	379.8	380.6	382.7	383.6	384.9	385.7	386.5	390.0	
425,000	378.5	379.2	380.3	381.1	383.2	384.1	385.4	386.2	387.0	390.5	
430,000	379.0	379.7	380.8	381.6	383.7	384.6	385.9	386.7	387.5	391.0	
435,000	379.5	380.2	381.3	382.1	384.2	385.1	386.4	387.2	388.0	391.5	
440,000	380.0	380.7	381.8	382.6	384.7	385.6	386.9	387.7	388.5	392.0	
445,000	380.5	381.2	382.3	383.1	385.2	386.1	387.4	388.2	389.0	392.5	
450,000	381.0	381.7	382.8	383.6	385.7	386.6	387.9	388.7	389.5	393.0	
455,000	381.5	382.2	383.3	384.1	386.2	387.1	388.4	389.2	390.0	393.5	
460,000	382.0	382.7	383.8	384.6	386.7	387.6	388.9	389.7	390.5	394.0	
465,000	382.5	383.2	384.3	385.1	387.2	388.1	389.4	390.2	391.0	394.5	
470,000	383.0	383.7	384.8	385.6	387.7	388.6	389.9	390.7	391.5	395.0	
475,000	383.5	384.2	385.3	386.1	388.2	389.1	390.4	391.2	392.0	395.5	
480,000	384.0	384.7	385.8	386.6	388.7	389.6	390.9	391.7	392.5	396.0	
485,000	384.5	385.2	386.3	387.1	389.2	390.1	391.4	392.2	393.0	396.5	
490,000	385.0	385.7	386.8	387.6	389.7	390.6	391.9	392.7	393.5	397.0	
495,000	385.5	386.2	387.3	388.1	390.2	391.1	392.4	393.2	394.0	397.5	
500,000	386.0	386.7	387.8								

DISCHARGE IN CFS	CONFLUENCE ELEVATION IN FEET ABOVE MEAN SEA LEVEL													
	335	337	339	340	342	344	346	348	350	352	354	356	358	360
0	335.0	337.0	339.0	340.0	342.0	344.0	346.0	348.0	350.0	352.0	354.0	356.0	358.0	360.0
5,000	335.2	337.1	339.1	340.0	342.0	344.0	346.0	348.0	350.0	352.0	354.0	356.0	358.0	360.0
10,000	335.7	337.4	339.2	340.2	342.1	344.1	346.0	348.0	350.0	352.0	354.0	356.0	358.0	360.0
15,000	336.4	337.8	339.4	340.3	342.2	344.1	346.1	348.1	350.0	352.0	354.0	356.0	358.0	360.0
20,000	337.1	338.2	339.7	340.6	342.3	344.2	346.1	348.1	350.1	352.1	354.1	356.1	358.1	360.1
25,000	337.9	338.8	340.1	340.8	342.5	344.3	346.2	348.2	350.1	352.1	354.1	356.1	358.1	360.1
30,000	338.6	339.3	340.5	341.2	342.7	344.5	346.3	348.2	350.2	352.2	354.2	356.2	358.2	360.2
35,000	339.3	339.9	340.9	341.5	343.0	344.6	346.4	348.3	350.2	352.2	354.2	356.2	358.2	360.2
40,000	339.9	340.4	341.3	341.9	343.2	344.8	346.6	348.4	350.3	352.2	354.2	356.2	358.2	360.2
45,000	340.4	340.9	341.7	342.2	343.4	344.9	346.7	348.5	350.3	352.2	354.2	356.2	358.2	360.2
50,000	340.9	341.3	342.0	342.5	343.7	345.1	346.9	348.7	350.5	352.3	354.1	355.9	357.7	359.5
55,000	341.3	341.7	342.4	342.9	344.1	345.5	347.3	349.1	350.9	352.7	354.5	356.3	358.1	359.9
60,000	341.8	342.2	342.9	343.4	344.6	345.9	347.7	349.5	351.3	353.1	354.9	356.7	358.5	360.3
65,000	342.2	342.6	343.3	343.8	345.0	346.4	348.2	350.0	351.8	353.6	355.4	357.2	359.0	360.8
70,000	342.6	343.0	343.7	344.2	345.4	346.8	348.6	350.4	352.2	354.0	355.8	357.6	359.4	361.2
75,000	343.0	343.4	344.1	344.6	345.8	347.2	349.0	350.8	352.6	354.4	356.2	358.0	359.8	361.6
80,000	343.4	343.8	344.5	345.0	346.2	347.6	349.4	351.2	353.0	354.8	356.6	358.4	360.2	362.0
85,000	343.8	344.2	344.9	345.4	346.6	348.0	349.8	351.6	353.4	355.2	357.0	358.8	360.6	362.4
90,000	344.2	344.6	345.3	345.8	347.0	348.4	350.2	352.0	353.8	355.6	357.4	359.2	361.0	362.8
95,000	344.6	345.0	345.7	346.2	347.4	348.8	350.6	352.4	354.2	356.0	357.8	359.6	361.4	363.2
100,000	345.0	345.4	346.1	346.6	347.8	349.2	351.0	352.8	354.6	356.4	358.2	360.0	361.8	363.6
105,000	345.4	345.8	346.5	347.0	348.2	349.6	351.4	353.2	355.0	356.8	358.6	360.4	362.2	364.0
110,000	345.8	346.2	346.9	347.4	348.6	350.0	351.8	353.6	355.4	357.2	359.0	360.8	362.6	364.4
115,000	346.2	346.6	347.3	347.8	349.0	350.4	352.2	354.0	355.8	357.6	359.4	361.2	363.0	364.8
120,000	346.6	347.0	347.7	348.2	349.4	350.8	352.6	354.4	356.2	358.0	359.8	361.6	363.4	365.2
125,000	347.0	347.4	348.1	348.6	349.8	351.2	353.0	354.8	356.6	358.4	360.2	362.0	363.8	365.6
130,000	347.4	347.8	348.5	349.0	350.2	351.6	353.4	355.2	357.0	358.8	360.6	362.4	364.2	366.0
135,000	347.8	348.2	348.9	349.4	350.6	352.0	353.8	355.6	357.4	359.2	361.0	362.8	364.6	366.4
140,000	348.2	348.6	349.3	349.8	351.0	352.8	354.6	356.4	358.2	360.0	361.8	363.6	365.4	367.2
145,000	348.6	349.0	349.7	350.2	351.4	352.8	354.6	356.4	358.2	360.0	361.8	363.6	365.4	367.2
150,000	349.0	349.4	350.1	350.6	351.8	353.2	355.0	356.8	358.6	360.4	362.2	364.0	365.8	367.6
155,000	349.4	349.8	350.5	351.0	352.2	353.6	355.4	357.2	359.0	360.8	362.6	364.4	366.2	368.0
160,000	349.8	350.2	350.9	351.4	352.6	354.0	355.8	357.6	359.4	361.2	363.0	364.8	366.6	368.4
165,000	350.2	350.6	351.3	351.8	353.0	354.4	356.2	358.0	359.8	361.6	363.4	365.2	367.0	368.8
170,000	350.6	351.0	351.7	352.2	353.4	354.8	356.6	358.4	360.2	362.0	363.8	365.6	367.4	369.2
175,000	351.0	351.4	352.1	352.6	353.8	355.2	357.0	358.8	360.6	362.4	364.2	366.0	367.8	369.6
180,000	351.4	351.8	352.5	353.0	354.2	355.6	357.4	359.2	361.0	362.8	364.6	366.4	368.2	370.0
185,000	351.8	352.2	352.9	353.4	354.6	356.0	357.8	359.6	361.4	363.2	365.0	366.8	368.6	370.4
190,000	352.2	352.6	353.3	353.8	355.0	356.4	358.2	360.0	361.8	363.6	365.4	367.2	369.0	370.8
195,000	352.6	353.0	353.7	354.2	355.4	356.8	358.6	360.4	362.2	364.0	365.8	367.6	369.4	371.2
200,000	353.0	353.4	354.1	354.6	355.8	357.2	359.0	360.8	362.6	364.4	366.2	368.0	369.8	371.6
205,000	353.4	353.8	354.5	355.0	356.2	357.6	359.4	361.2	363.0	364.8	366.6	368.4	370.2	372.0
210,000	353.8	354.2	354.9	355.4	356.6	358.0	359.8	361.6	363.4	365.2	367.0	368.8	370.6	372.4
215,000	354.2	354.6	355.3	355.8	357.0	358.4	360.2	362.0	363.8	365.6	367.4	369.2	371.0	372.8
220,000	354.6	355.0	355.7	356.2	357.4	358.8	360.6	362.4	364.2	366.0	367.8	369.6	371.4	373.2
225,000	355.0	355.4	356.1	356.6	357.8	359.2	361.0	362.8	364.6	366.4	368.2	370.0	371.8	373.6
230,000	355.4	355.8	356.5	357.0	358.2	359.6	361.4	363.2	365.0	366.8	368.6	370.4	372.2	374.0
235,000	355.8	356.2	356.9	357.4	358.6	360.0	361.8	363.6	365.4	367.2	369.0	370.8	372.6	374.4
240,000	356.2	356.6	357.3	357.8	359.0	360.4	362.2	364.0	365.8	367.6	369.4	371.2	373.0	374.8
245,000	356.6	357.0	357.7	358.2	359.4	360.8	362.6	364.4	366.2	368.0	369.8	371.6	373.4	375.2
250,000	357.0	357.4	358.1	358.6	359.8	361.2	363.0	364.8	366.6	368.4	370.2	372.0	373.8	375.6
255,000	357.4	357.8	358.5	359.0	360.2	361.6	363.4	365.2	367.0	368.8	370.6	372.4	374.2	376.0
260,000	357.8	358.2	358.9	359.4	360.6	362.0	363.8	365.6	367.4	369.2	371.0	372.8	374.6	376.4
265,000	358.2	358.6	359.3	359.8	361.0	362.4	364.2	366.0	367.8	369.6	371.4	373.2	375.0	376.8
270,000	358.6	359.0	359.7	360.2	361.4	362.8	364.6	366.4	368.2	370.0	371.8	373.6	375.4	377.2
275,000	359.0	359.4	360.1	360.6	361.8	363.2	365.0	366.8	368.6	370.4	372.2	374.0	375.8	377.6
280,000	359.4	359.8	360.5	361.0	362.2	363.6	365.4	367.2	369.0	370.8	372.6	374.4	376.2	378.0
285,000	359.8	360.2	360.9	361.4	362.6	364.0	365.8	367.6	369.4	371.2	373.0	374.8	376.6	378.4
290,000	360.2	360.6	361.3	361.8	363.0	364.4	366.2	368.0	369.8	371.6	373.4	375.2	377.0	378.8
295,000	360.6	361.0	361.7	362.2	363.4	364.8	366.6	368.4	370.2	372.0	373.8	375.6	377.4	379.2
300,000	361.0	361.4	362.1	362.6	363.8	365.2	367.0	368.8	370.6	372.4	374.2	376.0	377.8	379.6
305,000	361.4	361.8	362.5	363.0	364.2	365.6	367.4	369.2	371.0	372.8	374.6	376.4	378.2	380.0
310,000	361.8	362.2	362.9	363.4	364.6	366.0	367.8	369.6	371.4	373.2	375.0	376.8	378.6	380.4
315,000	362.2	362.6	363.3	363.8	365.0	366.4	368.2	370.0	371.8	373.6	375.4	377.2	379.0	380.8
320,000	362.6	363.0	363.7	364.2	365.4	366.8	368.6	370.4	372.2	374.0	375.8	377.6	379.4	381.2
325,000	363.0	363.4	364.1	364.6	365.8	367.2	369.0	370.8	372.6	374.4	376.2	378.0	379.8	381.6
330,000	363.4	363.8	364.5	365.0	366.2	367.6	369.4	371.2	373.0	374.8	376.6	378.4	380.2	382.0
335,000	363.8	364.2	364.9	365.4	366.6	368.0	369.8	371.6	373.4	375.2	377.0	378.8	380.6	382.4
340,000	364.2	364.6	365.3	365.8	367.0	368.4	370.2	372.0	373.8	375.6	377.4	379.2	381.0	382.8
345,000	364.6	365.0	365.7	366.2	367.4	368.8	370.6	372.4	374.2	376.0	377.8	379.6	381.4	383.2
350,000	365.0	365.4	366.1	366.6	367.8	369.2	371.0	372.8	374.6	376.4	378.2	380.0	381.8	383.6
355,000	365.4	365.8	366.5	367.0	368.2	369.6	371.4	373.2	375.0	376.8	378.6	380.4	382.2	384.0
360,000	365.8	366.2	366.9	367.4	368.6	370.0	371.8	373.6	375.4	377.2	379.0	380.8	382.6	384.4
365,000	366.2	366.6	367.3	367.8	369.0	370.4	372.2	374.0	375.8	377.6	379.4	381.2	383.0	384.8
370,000	366.6	367.0	367.7	368.2	369.4	370.8	372.6	374.4	376.2	378.0	379.8	381.6	383.4	385.2
375,000	367.0	367.4	368.1	368.6	369.8	371.2	373.0	374.8	376.6	378.4	380.2	382.0	383.8	385.6
380,000	367.4	367.8	368.5	369.0	370.2	371.6	373.4	375.2	377.0	378.8	380.6	382.4	384.2	386.0



#### NOTES:

1. COLUMBIA RIVER MILE 324.2 IS LOCATED AT THE CONFLUENCE OF THE SNAKE AND COLUMBIA RIVERS ON MCNARY RESERVOIR NEAR PASCO AND KENNEWICK, WASHINGTON.
2. WATER SURFACE ELEVATIONS WERE COMPUTED USING THE HYDROLOGIC ENGINEERING CENTER'S COMPUTER PROGRAM HEC-2 VERSION 4.6.2. THE CROSS SECTIONAL DATA FOR THE HEC-2 MODEL WAS OBTAINED FROM SEDIMENTATION RANGE SURVEYS CONDUCTED IN 1986.
3. THE HEC-2 MODEL WAS CALIBRATED USING ACTUAL FLOW DATA AND MEASURED WATER SURFACE PROFILES ALONG THE ENTIRE REACH OF THE MCNARY POOL. DISCHARGES USED IN THE CALIBRATIONS RANGE UP TO 300,000 CFS. THE AVERAGE ELEVATION ERROR OF THE DISCHARGE RATING CURVES IN THAT RANGE IS ABOUT 0.5 FEET. AT FLOWS UP TO 1,400,000 CFS, THE AVERAGE ESTIMATED ERROR INCREASES TO ABOUT 0.8 FEET, ALTHOUGH THE MAXIMUM REASONABLE ERROR COULD BE ABOUT 1.8 FEET.
4. EACH CURVE REPRESENTS COMPUTED WATER SURFACE ELEVATIONS FOR A RANGE OF DISCHARGES AND A SPECIFIC FOREBAY ELEVATION AT MCNARY DAM, LOCATED AT RIVER MILE 292.0. THE RIVER DISCHARGE APPLIES TO THE ENTIRE REACH FROM THE DAM UPSTREAM TO THE SNAKE RIVER CONFLUENCE.
5. SOURCE FOR SPILLWAY CAPACITIES WITH FREEFLOW CONDITIONS: TABLE 3-3, MCNARY WATER CONTROL MANUAL DATED AUGUST, 1989.

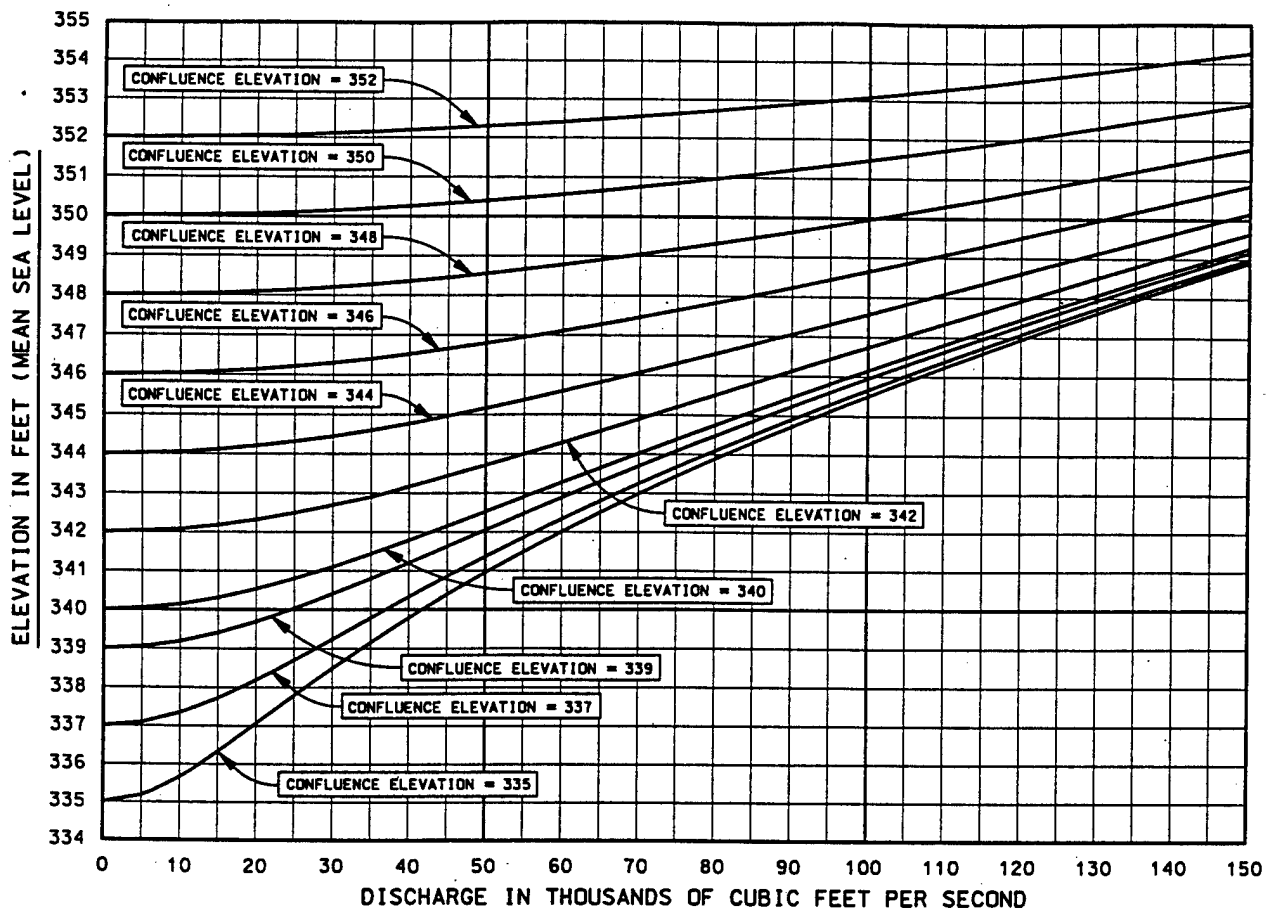
COLUMBIA RIVER BASIN, WASHINGTON

## DISCHARGE RATING CURVES AT RIVER MILE 324.2

U. S. ARMY ENGINEER DISTRICT  
WALLA WALLA - HYDROLOGY BRANCH

DESIGNED BY SPALDING  
DRAWN BY SCHUSTER  
DATE APR 1995

A00320



DISCHARGE (CFS)	CONFLUENCE ELEVATION IN FEET (MEAN SEA LEVEL)									
	335	337	339	340	342	344	346	348	350	352
160,000	349.5	349.6	349.8	349.9	350.2	350.7	351.3	352.2	353.3	354.6
180,000	350.7	350.8	350.9	351.0	351.3	351.6	352.2	353.0	353.9	355.1
200,000	351.8	351.8	351.9	352.0	352.3	352.6	353.1	353.7	354.6	355.7
250,000	354.2	354.3	354.4	354.4	354.6	354.8	355.2	355.7	356.3	357.2
300,000	356.5	356.5	356.6	356.6	356.7	356.9	357.2	357.5	358.1	358.7
350,000	358.5	358.5	358.6	358.6	358.7	358.8	359.0	359.3	359.7	360.3
400,000	360.4	360.4	360.4	360.5	360.5	360.6	360.8	361.0	361.4	361.8
450,000	362.1	362.2	362.2	362.2	362.3	362.3	362.5	362.7	362.9	363.3
550,000	365.4	365.4	365.4	365.4	365.4	365.5	365.6	365.7	365.9	366.2
650,000	368.3	368.3	368.3	368.3	368.3	368.4	368.4	368.5	368.7	368.9
750,000	371.0	371.0	371.0	371.0	371.0	371.0	371.1	371.2	371.3	371.4
850,000	373.6	373.6	373.6	373.6	373.6	373.6	373.6	373.6	373.7	373.8

COMPUTED WATER SURFACE ELEVATIONS IN FEET (MEAN SEA LEVEL)

#### NOTES:

1. SNAKE RIVER MILE 9.23 IS LOCATED APPROXIMATELY 2,000 FEET DOWNSTREAM OF THE EDGE OF THE POWERHOUSE TAILRACE DECK ON ICE HARBOR DAM.
2. WATER SURFACE ELEVATIONS WERE COMPUTED USING THE HYDROLOGIC ENGINEERING CENTER'S COMPUTER PROGRAM HEC-2 VERSION 4.6.2. RIVER CHANNEL GEOMETRIC DATA WAS OBTAINED FROM FIELD SURVEYS IN 1978, 1981, AND 1994. OVERBANK GEOMETRIC DATA WAS OBTAINED FROM TOPOGRAPHIC MAPS WITH 10-FOOT CONTOUR INTERVALS. THE MAPPING WAS BASED ON 1956 AND 1957 AERIAL PHOTOGRAMMETRY.
3. THE HEC-2 MODEL WAS CALIBRATED USING ACTUAL FLOW DATA AND MEASURED TAILWATER ELEVATIONS AT ICE HARBOR DAM FOR DISCHARGES UP TO 169,000 CFS. THE AVERAGE ELEVATION ERROR OF THE DISCHARGE RATING CURVES IN THAT RANGE IS ABOUT 0.3 FEET. AT FLOWS UP TO 850,000 CFS THE AVERAGE ESTIMATED ERROR INCREASES TO ABOUT 0.7 FEET. ALTHOUGH THE MAXIMUM REASONABLE ERROR COULD BE ABOUT 1.5 FEET.
4. EACH CURVE REPRESENTS COMPUTED WATER SURFACE ELEVATIONS FOR A RANGE OF DISCHARGES AND A SPECIFIC WATER SURFACE ELEVATION AT THE MOUTH OF THE SNAKE RIVER. THE CONFLUENCE OF THE SNAKE AND COLUMBIA RIVERS IS LOCATED AT COLUMBIA RIVER MILE 324.2. THE RIVER DISCHARGE APPLIES TO THE ENTIRE SNAKE RIVER REACH FROM THE CONFLUENCE UPSTREAM TO ICE HARBOR DAM.

SNAKE RIVER BASIN, WASHINGTON

## DISCHARGE RATING CURVES AT RIVER MILE 9.23

U. S. ARMY ENGINEER DISTRICT  
WALLA WALLA - HYDROLOGY BRANCH

A00321

DESIGNED

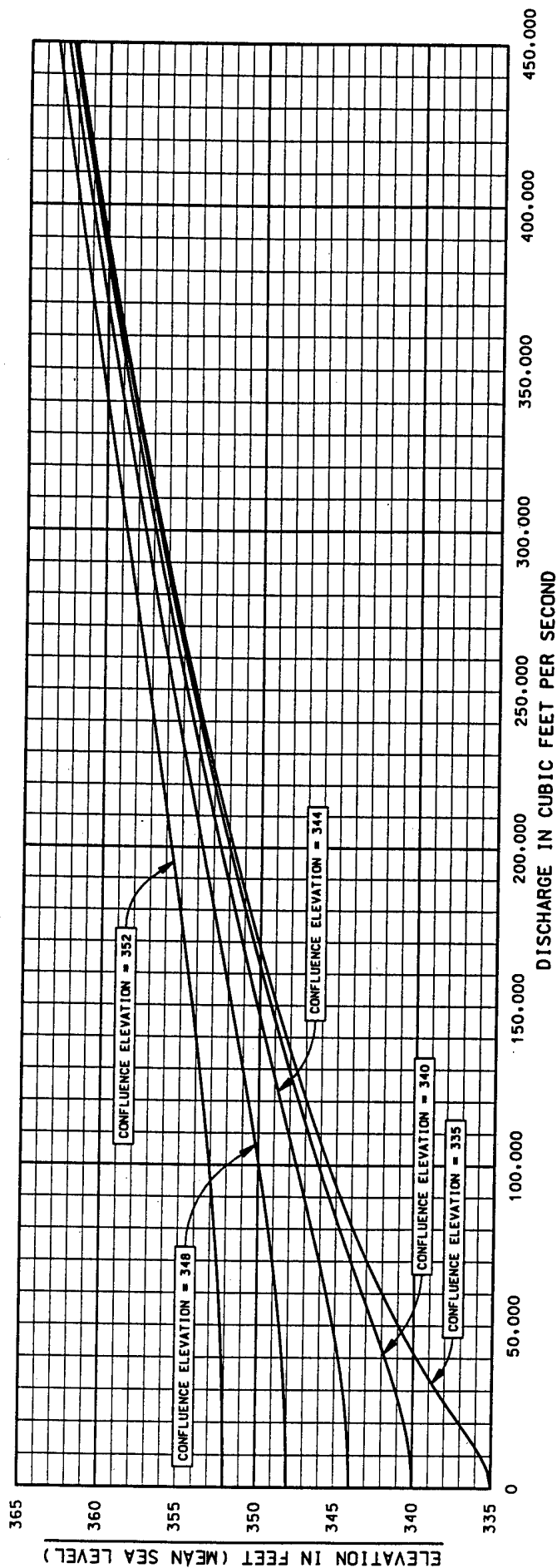
SPAULDING

DRAWN

SCHUSTER

DATE

APR 1995



DISCHARGE (CFS)	CONFLUENCE ELEVATION IN FEET (MSL)				
	335	340	344	348	352
550,000	365.4	365.4	365.5	365.7	366.2
650,000	368.3	368.3	368.4	368.5	368.9
750,000	371.0	371.0	371.0	371.2	371.4
850,000	373.6	373.6	373.6	373.6	373.8

COMPUTED WATER SURFACE ELEVATIONS  
IN FEET MEAN SEA LEVEL

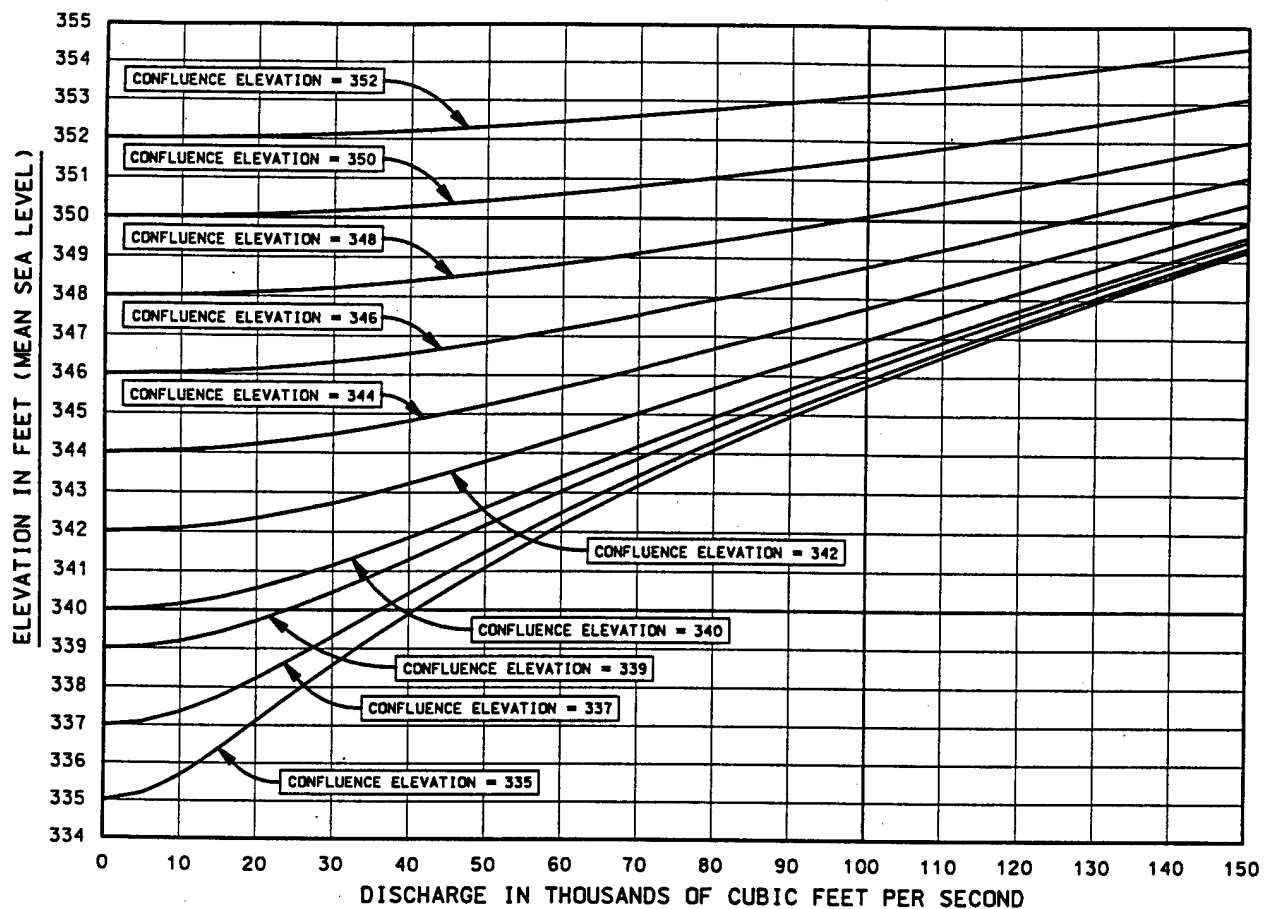
NOTES:

1. SNAKE RIVER MILE 9.23 IS LOCATED APPROXIMATELY 2,000 FEET DOWNSTREAM OF THE EDGE OF THE POWERHOUSE TAILRADE DECK ON ICE HARBOR DAM.
2. WATER SURFACE ELEVATIONS WERE COMPUTED USING THE HYDROLOGIC ENGINEERING CENTER'S COMPUTER PROGRAM HEC-2 VERSION 4.6.2. RIVER CHANNEL GEOMETRIC DATA WAS OBTAINED FROM FIELD SURVEYS IN 1978, 1981, AND 1994. OVERBANK GEOMETRIC DATA WAS OBTAINED FROM TOPOGRAPHIC MAPS WITH 10-FOOT CONTOUR INTERVALS. THE MAPPING WAS BASED ON 1956 AND 1957 AERIAL PHOTOGRAMMETRY.
3. THE HEC-2 MODEL WAS CALIBRATED USING ACTUAL FLOW DATA AND MEASURED TAILWATER ELEVATIONS AT ICE HARBOR DAM FOR DISCHARGES UP TO 169,000 CFS. THE AVERAGE ELEVATION ERROR OF THE DISCHARGE RATING CURVES IN THAT RANGE IS ABOUT 0.3 FEET. AT FLOWS UP TO 850,000 CFS THE AVERAGE ESTIMATED ERROR INCREASES TO ABOUT 0.7 FEET, ALTHOUGH THE MAXIMUM REASONABLE ERROR COULD BE ABOUT 1.5 FEET.
4. EACH CURVE REPRESENTS COMPUTED WATER SURFACE ELEVATIONS FOR A RANGE OF DISCHARGES AND A SPECIFIC WATER SURFACE ELEVATION AT THE MOUTH OF THE SNAKE RIVER. THE CONFLUENCE OF THE SNAKE AND COLUMBIA RIVERS IS LOCATED AT COLUMBIA RIVER MILE 324.2. THE RIVER DISCHARGE APPLIES TO THE ENTIRE SNAKE RIVER REACH FROM THE CONFLUENCE UPSTREAM TO ICE HARBOR DAM.

SNAKE RIVER BASIN, WASHINGTON  
**DISCHARGE  
RATING CURVES  
AT RIVER MILE 9.23**  
 U. S. ARMY ENGINEER DISTRICT  
 WALLA WALLA - HYDROLOGY BRANCH

DESIGNED  
 SPAULDING  
 DRAWN  
 SCHUSTER  
 DATE  
 APR 1995

A00326



DISCHARGE (CFS)	CONFLUENCE ELEVATION IN FEET (MEAN SEA LEVEL)									
	335	337	339	340	342	344	346	348	350	352
160,000	349.9	350.0	350.1	350.2	350.5	351.0	351.6	352.4	353.5	354.7
180,000	351.1	351.1	351.3	351.3	351.6	352.0	352.5	353.2	354.2	355.3
200,000	352.2	352.2	352.3	352.4	352.6	353.0	353.4	354.1	354.9	355.9
250,000	354.7	354.7	354.8	354.9	355.0	355.3	355.6	356.1	356.7	357.5
300,000	357.0	357.0	357.1	357.1	357.2	357.4	357.6	358.0	358.5	359.1
350,000	359.1	359.1	359.1	359.1	359.2	359.3	359.5	359.8	360.2	360.7
400,000	361.0	361.0	361.0	361.0	361.1	361.2	361.3	361.5	361.9	362.3
450,000	362.7	362.7	362.7	362.8	362.8	362.9	363.0	363.2	363.4	363.8
550,000	365.9	365.9	366.0	366.0	366.0	366.1	366.1	366.3	366.4	366.7
650,000	368.9	368.9	368.9	368.9	368.9	368.9	369.0	369.1	369.2	369.4
750,000	371.6	371.6	371.6	371.6	371.6	371.6	371.6	371.7	371.8	371.9
850,000	374.1	374.1	374.1	374.1	374.1	374.1	374.1	374.1	374.2	374.3

COMPUTED WATER SURFACE ELEVATIONS IN FEET (MEAN SEA LEVEL)

#### NOTES:

1. SNAKE RIVER MILE 9.42 IS LOCATED APPROXIMATELY 1,000 FEET DOWNSTREAM OF THE EDGE OF THE POWERHOUSE TAILRACE DECK ON ICE HARBOR DAM.
2. WATER SURFACE ELEVATIONS WERE COMPUTED USING THE HYDROLOGIC ENGINEERING CENTER'S COMPUTER PROGRAM HEC-2 VERSION 4.6.2. RIVER CHANNEL GEOMETRIC DATA WAS OBTAINED FROM FIELD SURVEYS IN 1978, 1981, AND 1994. OVBANK GEOMETRIC DATA WAS OBTAINED FROM TOPOGRAPHIC MAPS WITH 10-FOOT CONTOUR INTERVALS. THE MAPPING WAS BASED ON 1956 AND 1957 AERIAL PHOTOGRAMMETRY.
3. THE HEC-2 MODEL WAS CALIBRATED USING ACTUAL FLOW DATA AND MEASURED TAILWATER ELEVATIONS AT ICE HARBOR DAM FOR DISCHARGES UP TO 169,000 CFS. THE AVERAGE ELEVATION ERROR OF THE DISCHARGE RATING CURVES IN THAT RANGE IS ABOUT 0.3 FEET. AT FLOWS UP TO 850,000 CFS THE AVERAGE ESTIMATED ERROR INCREASES TO ABOUT 0.7 FEET. ALTHOUGH THE MAXIMUM REASONABLE ERROR COULD BE ABOUT 1.5 FEET.
4. EACH CURVE REPRESENTS COMPUTED WATER SURFACE ELEVATIONS FOR A RANGE OF DISCHARGES AND A SPECIFIC WATER SURFACE ELEVATION AT THE MOUTH OF THE SNAKE RIVER. THE CONFLUENCE OF THE SNAKE AND COLUMBIA RIVERS IS LOCATED AT COLUMBIA RIVER MILE 324.2. THE RIVER DISCHARGE APPLIES TO THE ENTIRE SNAKE RIVER REACH FROM THE CONFLUENCE UPSTREAM TO ICE HARBOR DAM.

SNAKE RIVER BASIN, WASHINGTON

## DISCHARGE RATING CURVES AT RIVER MILE 9.42

U. S. ARMY ENGINEER DISTRICT  
WALLA WALLA - HYDROLOGY BRANCH

A00322

DESIGNED

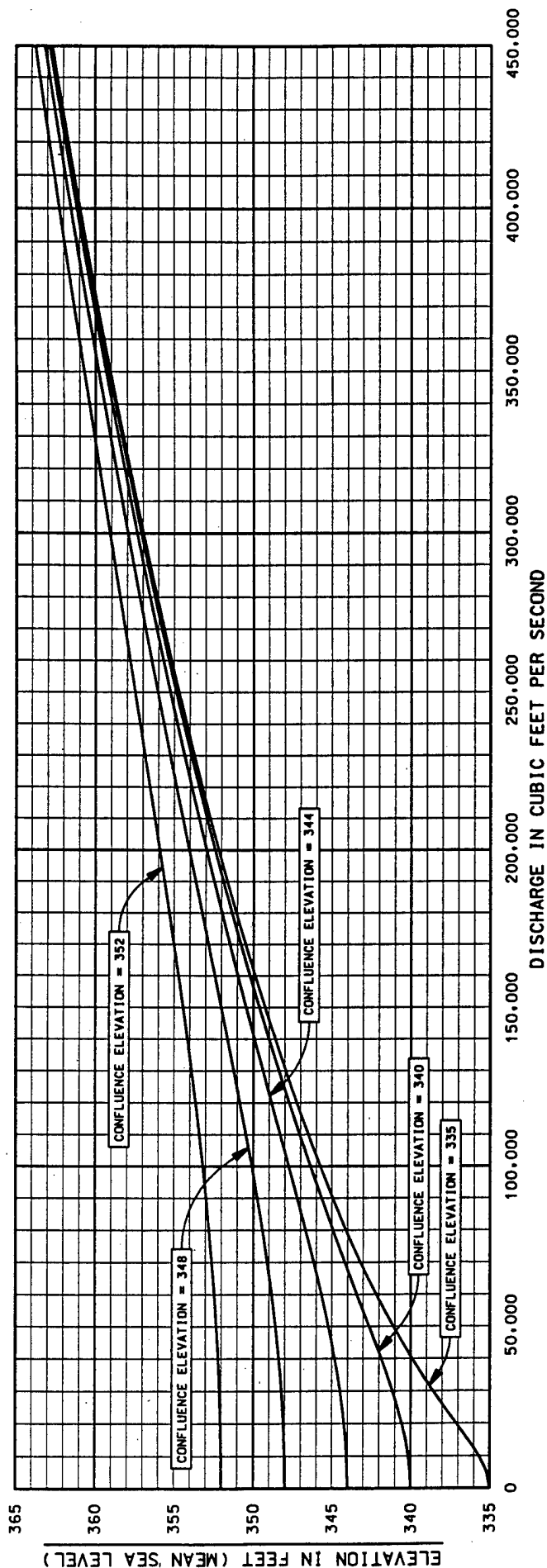
SPAULDING

DRAWN

SCHUSTER

DATE

APR 1995



DISCHARGE (CFS)	CONFLUENCE ELEVATION IN FEET (MSL)				
	335	340	344	348	352
550,000	365.9	366.0	366.1	366.3	366.7
650,000	368.9	368.9	368.9	369.1	369.4
750,000	371.6	371.6	371.6	371.7	371.9
850,000	374.1	374.1	374.1	374.1	374.3

COMPUTED WATER SURFACE ELEVATIONS  
IN FEET MEAN SEA LEVEL

#### NOTES:

1. SNAKE RIVER MILE 9.42 IS LOCATED APPROXIMATELY 1,000 FEET DOWNSTREAM OF THE EDGE OF THE POWERHOUSE TAILRACE DECK ON ICE HARBOR DAM.
2. WATER SURFACE ELEVATIONS WERE COMPUTED USING THE HYDROLOGIC ENGINEERING CENTER'S COMPUTER PROGRAM HEC-2 VERSION 4.6.2. RIVER CHANNEL GEOMETRIC DATA WAS OBTAINED FROM FIELD SURVEYS IN 1978, 1981, AND 1994. OVBANK GEOMETRIC DATA WAS OBTAINED FROM TOPOGRAPHIC MAPS WITH 10-FOOT CONTOUR INTERVALS. THE MAPPING WAS BASED ON 1956 AND 1957 AERIAL PHOTOGRAMMETRY.
3. THE HEC-2 MODEL WAS CALIBRATED USING ACTUAL FLOW DATA AND MEASURED TAILWATER ELEVATIONS AT ICE HARBOR DAM FOR DISCHARGES UP TO 169,000 CFS. THE AVERAGE ELEVATION ERROR OF THE DISCHARGE RATING CURVES IN THAT RANGE IS ABOUT 0.3 FEET. AT FLOWS UP TO 850,000 CFS THE AVERAGE ESTIMATED ERROR INCREASES TO ABOUT 0.7 FEET, ALTHOUGH THE MAXIMUM REASONABLE ERROR COULD BE ABOUT 1.5 FEET.
4. EACH CURVE REPRESENTS COMPUTED WATER SURFACE ELEVATIONS FOR A RANGE OF DISCHARGES AND A SPECIFIC WATER SURFACE ELEVATION AT THE MOUTH OF THE SNAKE RIVER. THE CONFLUENCE OF THE SNAKE AND COLUMBIA RIVERS IS LOCATED AT COLUMBIA RIVER MILE 324.2. THE RIVER DISCHARGE APPLIES TO THE ENTIRE SNAKE RIVER REACH FROM THE CONFLUENCE UPSTREAM TO ICE HARBOR DAM.

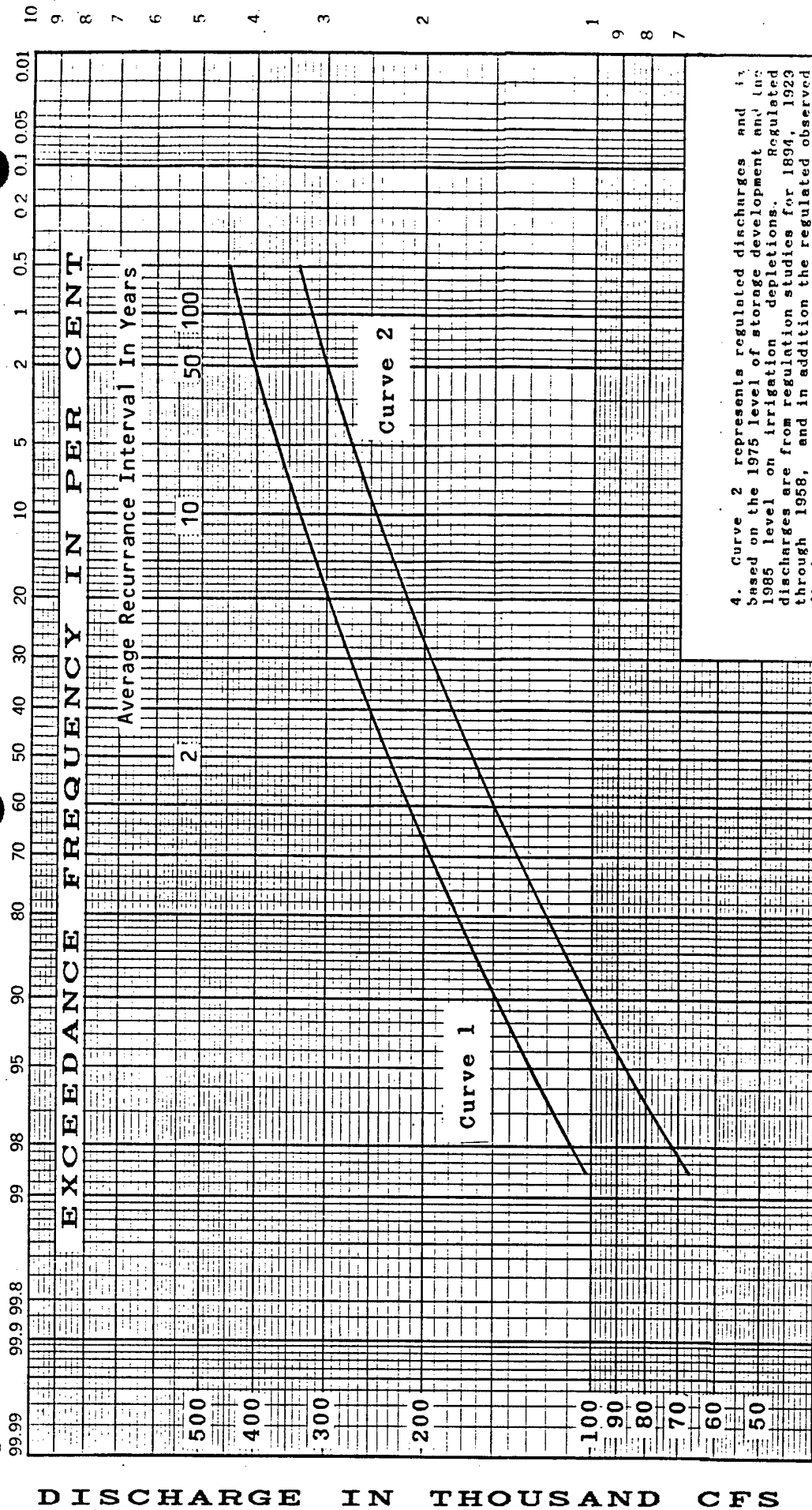
SNAKE RIVER BASIN, WASHINGTON

## DISCHARGE RATING CURVES AT RIVER MILE 9.42

U. S. ARMY ENGINEER DISTRICT  
WALLA WALLA - HYDROLOGY BRANCH

DESIGNED SPAULDING DRAWN SCHUSTER DATE APR 1995

A00327



4. Curve 2 represents regulated discharges and is based on the 1975 level of storage development and the 1985 level on irrigation depletions. Regulated discharges are from regulation studies for 1894, 1923 through 1958, and in addition the regulated observed discharges for the high runoff years of 1972 and 1974. The plotting positions for the regulated event years are for the natural frequency curve. Curve 2 is a graphical fit of the regulated data.

#### NOTES

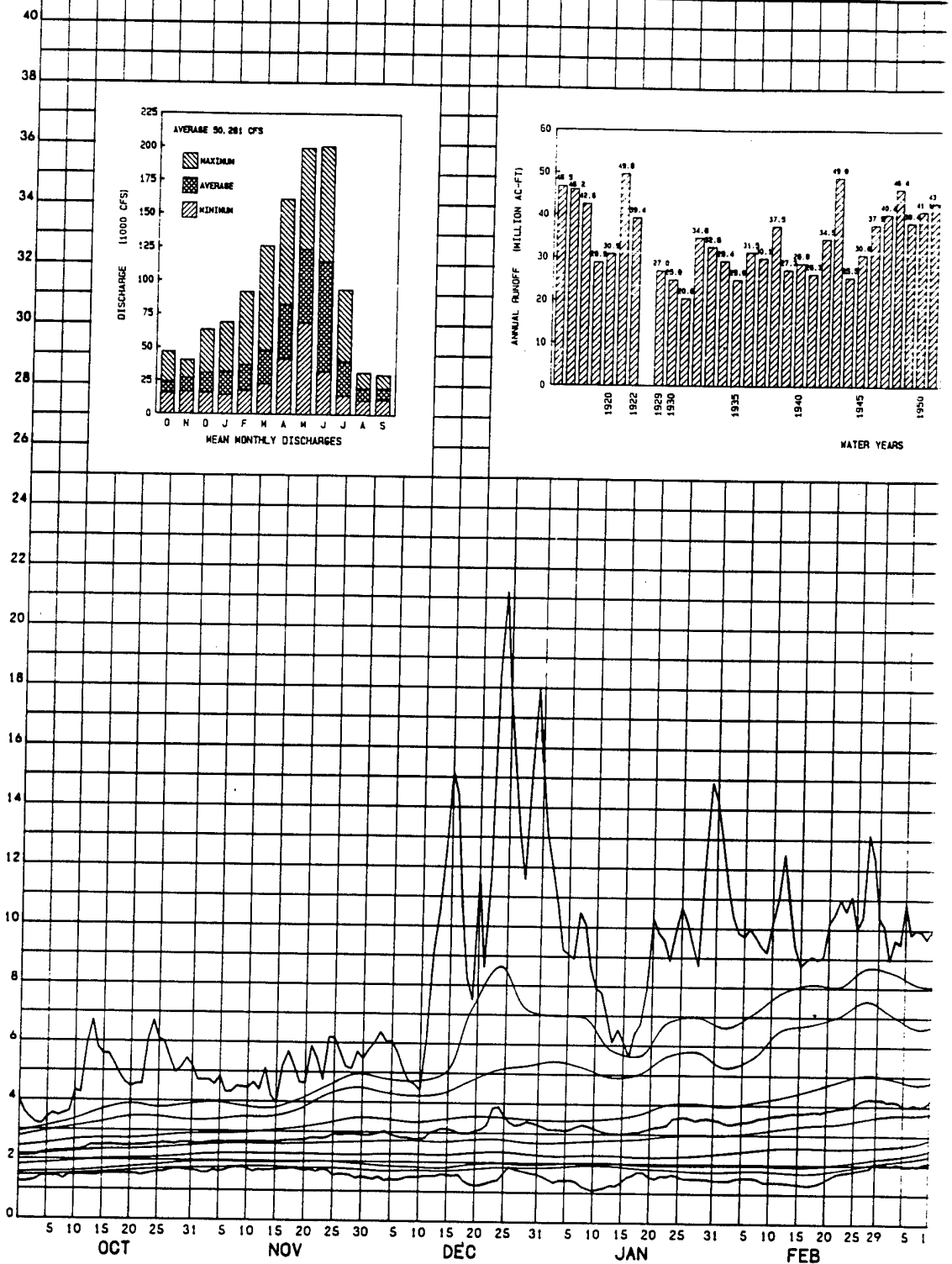
1. Drainage area equals 103,200 sq. mi.
2. This is a preliminary graph subject to revision.
3. Curve 1 represents natural discharges and is based on the 1894-1975 station record adjusted for irrigation depletions and storage and extended by correlation with the 1858-1975 Columbia River at The Dalles station record. It includes an expected probability adjustment. The station and adopted skew is -0.5. Natural discharges for the 1894-1975 period of record are plotted based on their ranking within the extended record. The median plotting position method was utilized.

### ICE HARBOR LOCK AND DAM SNAKE RIVER, WASHINGTON

#### ANNUAL PEAK DISCHARGE FREQUENCIES Snake River At Lower Granite Dam

U.S. Army Engineer Division, N.P.  
NPDEN-WM-IIES May 1978

DISCHARGE IN 10,000 CFS

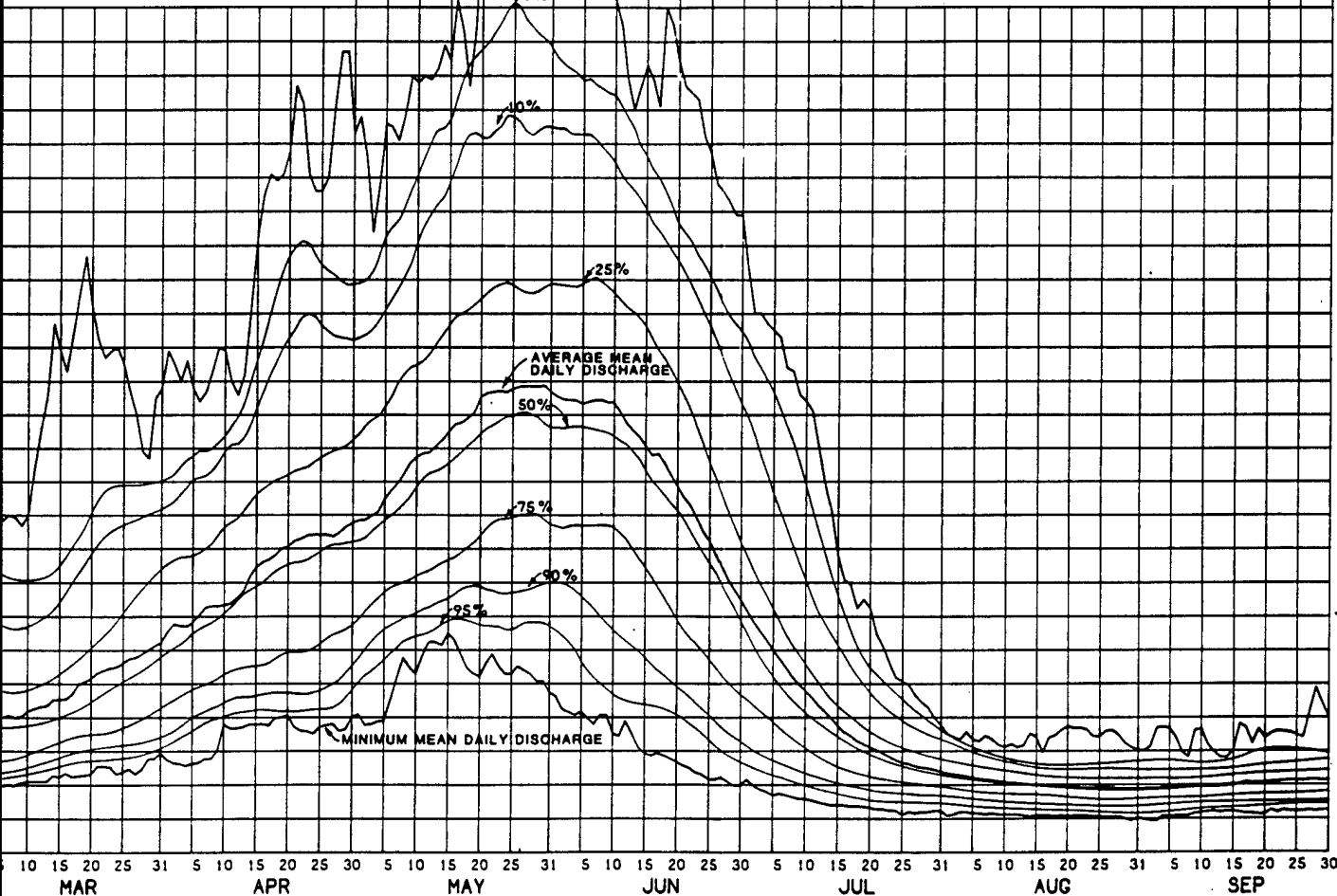
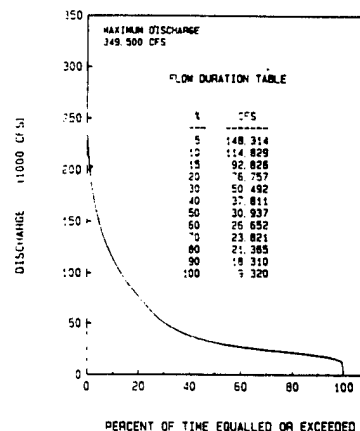
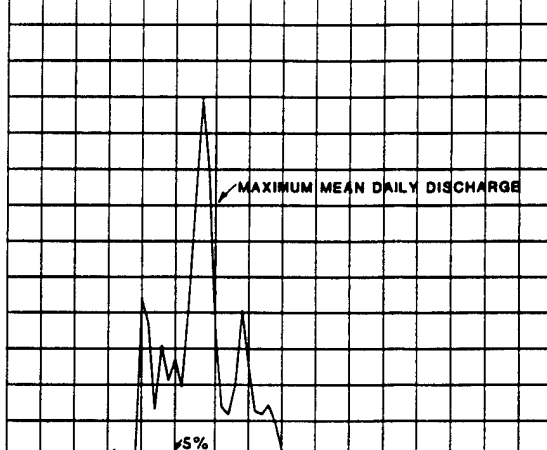
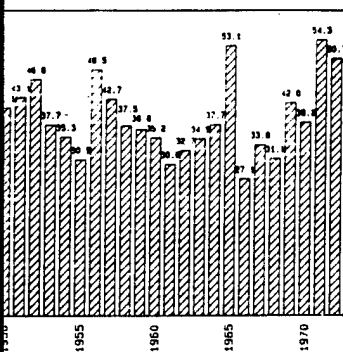


## NOTES:

## RECORDS USED:

- WATER YEARS 1916-1922 AND 1929-1935, OBSERVED DISCHARGES AT RIVARIA, WASHINGTON. DRAINAGE AREA IS 104,000 SQUARE MILES.
- WATER YEARS 1936-1972, OBSERVED DISCHARGES AT CLARKSTON, WASHINGTON. DRAINAGE AREA IS 103,200 SQUARE MILES.
- DISCHARGE RECORDS USED ARE FROM DATA PUBLISHED BY U.S.G.S.
- DISCHARGE RECORDS AT CLARKSTON AND RIVARIA HAVE BEEN CONSIDERED COMPARABLE AND HAVE BEEN USED WITHOUT CORRECTIONS FOR INCIDENTAL INFLOW BETWEEN THESE STATIONS.
- DISCHARGES USED ARE THOSE OBSERVED AT THE TIME AND REFLECT VARYING EFFECTS OF PROGRESSIVE IRRIGATION AND RESERVOIR STORAGE DEVELOPMENTS.
- CURVES OF PERCENT CHANCE OF OCCURRENCE REPRESENT THE AVERAGE DAILY DISCHARGE FOR THAT DAY. A POINT ON AN EXCEEDENCE CURVE REPRESENTS THE AVERAGE DAILY DISCHARGE FOR A SPECIFIC DAY WHICH HAS BEEN EXCEEDED THE GIVEN PERCENTAGE OF TIME.

WATER YEAR	DATE	MAXIMUM AN	
		DATE	CF
1916	JUN 20	230.0	
1917	MAY 30	256.0	
1918	JUN 14	276.0	
1919	MAY 30	267.0	
1920	JUN 17	280.0	
1921	MAY 20	270.0	
1922	JUN 7	233.0	
1929	MAY 25	255.0	
1930	APR 26	255.0	
1931	APR 2	277.0	
1932	MAY 23	279.0	
1933	JUN 11	245.0	
1934	DEC 23	249.0	
1935	MAY 25	232.0	
1937	MAY 19	230.0	
1938	MAY 29	234.0	
1939	MAY 4	240.0	
1940	MAY 13	230.0	
1941	MAY 14	222.0	



ANNUAL MEAN DAILY DISCHARGES			
CFS	WATER YEAR	DATE	CFS
30,000	1942	MAY 27	158,000
36,000	1943	APR 20	208,000
46,000	1944	MAY 16	105,600
67,000	1945	JUN 7	148,000
48,000	1946	APR 20	166,000
70,000	1947	MAY 9	23,000
33,000	1948	MAY 29	349,500
55,000	1949	MAY 17	243,100
95,600	1950	JUN 17	100,000
37,000	1951	MAY 25	179,000
19,000	1952	APR 28	237,000
45,000	1953	JUN 14	226,000
49,000	1954	MAY 27	204,000
32,000	1955	JUN 13	199,000
10,000	1956	MAY 25	277,100
4,000	1957	MAY 20	293,800
44,000	1958	MAY 22	239,800
5,000	1959	JUN 7	67,600
32,000	1960	JUN 5	157,400

MAXIMUM ANNUAL MEAN DAILY DISCHARGES					
WATER YEAR	DATE	CFS	WATER YEAR	DATE	CFS
1961	MAY 27	168,000			
1963	MAY 25	150,400			
1964	JUN 9	240,300			
1965	APR 21	227,000			
1966	MAY 8	111,000			
1967	MAY 24	205,000			
1968	JUN 4	129,000			
1969	MAY 30	182,000			
1970	JUN 7	227,000			
1971	MAY 30	253,000			
1972	JUN 2	237,000			

REVISION		DATE	DESCRIPTION	CHECK	APPROVED
U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON					
<b>ICE HARBOR LOCK &amp; DAM</b> SNAKE RIVER, OREGON, WASHINGTON, & IDAHO SUMMARY HYDROGRAPHS SNAKE RIVER NEAR CLARKSTON, WASH.					
DESIGNED BY D. Brooks		APPROVED			
CHECKED BY Gerber Plotter		DATE			
EXAMINED BY E. Kim		SCALE AS SHOWN			
SUBMITTED BY L. Kim		SHEET NO.			
RECORDED BY L. Kim		FILE NO.			
CHECKED BY L. Kim		DATE			

## **APPENDIX B**

### **Hydraulic Model Study Information**

- a. Dissolved Gas Abatement  
Phase I - Technical Report - Appendix G**
- b. Data Report for Ice Harbor Sectional Model**

## MEMORANDUM FOR RECORD

SUBJECT: Physical Model Studies in the Dissolved Gas Abatement Studies

1. General. Physical models of hydraulic structures are valuable tools for visualizing flow patterns, evaluating hydraulic performance, and estimating hydraulic conditions that will exist in a full-scale structure. As a general rule, however, direct measurements of gas super-saturation for scaling from model to full scale structure are not possible. Two of the main processes that dictate gas transfer performance are not scaleable parameters in physical hydraulic models.
2. Even a relatively large-scale hydraulic model will introduce some level of distortion for gas absorption from bubbles or through the water surface. Bubbles, in a physical model, are very large compared to those that will be encountered in the full scale structure. As a consequence, the buoyant forces on the bubbles are greatly exaggerated compared to the full scale. The large buoyant force allows bubbles to escape the flow much quicker than will be occurring in the full scale structure. The effects of this distortion show up when tracking the extent of an entrained air plume in a model. The model plume is attenuated in length and in depth. This translates to much longer relative contact times and greater gas transfer in the full scale structure than in the physical model. Additionally, since the bubbles are not properly scaled, then the surface area available for gas transfer is likewise, improperly scaled.
3. When aerated plunging flows exist (bubbles being transported to the full depth of the stilling basin), the bubbles experience significant increases in hydrostatic pressure, which causes an increase in the saturation concentration of the oxygen and nitrogen in the bubbles. This increase in saturation is the process that allows supersaturated conditions to develop. In a physical model, the large depth does not exist to create the higher-than-atmospheric pressure. Thus, supersaturated conditions cannot be modeled in most hydraulic models.
4. The value of hydraulic models in gas transfer processes lies in flow visualization and alternative comparison. A clear understanding the flow conditions that contribute to increased gas transfer provides a basis for assessing alternative designs in a physical model. For example, the hydrologic and geometric conditions that produce plunging flow conditions can be easily determined. Alternatives that avoid these conditions or modify flow patterns to something more acceptable can be identified. Measurable parameters in physical models, such as hydraulic performance or velocity, may contribute to understanding gas transfer, but usually only qualitative conclusions can be drawn.

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5. This line of reasoning suggests that careful observation of alternative designs can permit qualitative assessments of gas transfer performance. One design can be ranked as a "better" design compared to another based on avoidance of plunging aerated flow patterns or other condition conducive to dissolved gas absorption. In some instances, where observed gas transfer data exist, quantitative estimates of gas transfer may be developed.

6. Sectional Spillway Model Studies. Presently, at the U.S. Army Engineer Waterways Experiment Station, four spillway structures are reproduced in sectional models:

Project	Number of Spillways in model	Scale
Lower Granite	1 plus 2 half-bays	1:55
Ice Harbor	3 plus 2 half-bays	1:40
John Day	3 plus 2 half-bays	1:40
The Dalles	5 plus 2 half-bays	1:40

7. Experimental work in the Lower Granite model is much further along than in The Dalles model study. However, the objectives of testing the various sectional models are similar: define flow patterns that contribute to or reduce opportunity for gas absorption in the stilling basin. Various stilling basin designs or modifications or operational alternatives are under study. Although the following discussion focuses on the Ice Harbor sectional model, the approach and results of testing should be applicable to any of the other projects.

8. Ice Harbor Sectional Model. The Ice Harbor sectional model has been used to study flow conditions for four alternative designs or stilling basin modifications, listed below. The observations from the model tests are summarized and discussed in succeeding paragraphs.

a. Flow patterns in the existing stilling basin were examined and documented on video and in photographs.

b. A series of alternative deflectors was tested, including a 12.5-ft long deflector with no toe-radius (only a small fillet at the spillway face), a 12.5-ft long deflector with a 15-ft toe radius (similar to the Lower Granite design), and a 12.5-ft long flip-lip (deflector with an upward flip at its downstream end). The flow patterns were documented on video tape.

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c. A small 4.2-ft long deflector was studied. The flow patterns established by this design was documented on video tape.

d. A raised stilling basin is currently being tested. Performance characteristics are likewise being recorded on video.

9. Existing Design. Figure 1 shows single gate operation in the existing stilling basin for a spillbay discharge of 5,900 cfs. The obvious plunging flow at the spillway nappe causes large amounts of air entrainment. The bubbles are transported with the water to the full depth of the stilling basin. As a consequence, they are subjected to very high hydrostatic pressures, which is the major force in gas absorption to supersaturated levels. The objective of alternative designs is to reduce or eliminate the plunging flow and transport of air bubbles to depth.

10. Spillway Deflectors. Deflectors were initially screened by assessing their performance characteristics for different discharges and tailwater elevations. The initial deflector (Type 1 Deflector, shown in Figure 2) had been developed at the Bonneville Hydraulic Laboratory. It was 12.5 ft long with a small-radius fillet at the spillway face. The flow conditions created by the deflector in the stilling basin were extremely turbulent. The nappe of water on the spillway collided with the deflector causing large highly-aerated waves to form in the stilling basin. Air bubbles were easily transported to depth because of the plunging nature of flow induced by the waves. It appeared that improvements to the deflector could improve the flow conditions and reduce the penchant for transporting bubbles to deep water.

11. An alternative design (Type 1 Flip-lip shown in Figure 3) was developed that consisted of a 12.5 ft long deflector with 15-ft toe radius at the spillway and a 1-ft high flip-lip at the downstream end of the deflector. We expected the toe radius to reduce the effects of nappe impact on the deflector by actually redirecting the flow like an elbow. The flip-lip was expected to deflect the water upward and reduce the downward velocities of the nappe and thereby reduce plunging action. The toe radius performed very well, smoothly deflecting the nappe. However, the flip-lip served only to "launch" the flow at normal tailwater elevations. The airborne aerated nappe plunged into the stilling basin at the baffle blocks, entraining air and producing flow patterns as bad or worse than the Type 1 Deflector.

12. The Type 2 Deflector design (Figure 4) was similar to the deflector installed at Lower Granite: 12.5 ft long with a 15-ft toe radius at the spillway which acted as a fillet to smooth the nappe transition between the spillway and the deflector. Tests conducted

with this design showed significant improvements for flows of up to 5,900 cfs per bay compared to the other designs. Testing with flows of 2,500 cfs per bay and 5,900 cfs per bay showed that with very low tailwater, the underside of the nappe would be aerated and the flow would plunge to the stilling basin floor. This condition entrained large volumes of air and transported air bubbles to depth in the stilling basin and tailrace area. As the tailwater elevation was increased, the venting of the nappe was inconsistent and produced an unstable condition with periods of the flow alternately plunging to the stilling basin floor or attempting to ride the surface of the tailwater. When the tailwater elevation was sufficient to prevent aeration at the downstream edge of the deflector, the flow jet remained along the surface of the tailwater and produced the desired "skimming" flow conditions. The skimming condition was observed with submergences of 2-8 ft for a spillbay discharge of 2,500 cfs and submergences of 8-11 ft for spillbay discharges of 5,900 cfs. With higher submergences, the nappe would ride up on the down-stream water surface forming an undulatory jump and causing large standing waves and plunging flows in the vicinity of the baffle blocks. With extremely high tailwater (higher than would be encountered at these discharges), the nappe would finally submerge resulting in a submerged hydraulic jump that is elevated off of the stilling basin floor by the deflector. Tests were also conducted for flows of 8,000, 10,000, 12,100, and 17,500 cfs per bay. With low tailwaters, plunging flow conditions existed. As the tailwater was raised, the unstable flow condition formed as previously described. However, as the tailwater was raised further, the skimming flow condition did not form and the nappe rode up on the downstream water surface causing standing waves and plunging flows, thus no satisfactory flow conditions were observed for the higher discharges.

13. Deflector Flow Analysis. An analysis of deflector flow suggests that their performance characteristics can be defined as a function of deflector submergence and spillway discharge. Figure 5 shows the performance curves for the Type 2 Deflector as a function of submergence and spillbay discharge. These curves provide a basis for siting the deflector elevation for best performance and for determining if the operational range of acceptable performance is sufficient. For example, at Ice Harbor, skimming flow will occur with a submergence of 2-8 ft for the Type 2 Deflector with spillbay discharge of 2,500 cfs. For a normal tailwater elevation of approximately 345 ft, the deflector would have to be located at el 343 and would provide skimming flow for a tailwater range of 345 ft to 353 ft. Alternately, for a submergence of 8 ft with tailwater at el 345, spillbay discharge could range from 2,500 cfs per bay to 5,900 cfs per bay and still result in skimming flow.

14. Dimensionally-Challenged (small) Deflector. A much-smaller deflector (Figure 6) was also investigated to determine its operating characteristics. A narrower band of satisfactory flow conditions was observed compared to the Type 2 Deflector. With a spillbay discharge of 2,500 cfs, the skimming flow condition existed for submergences

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of 1-4 ft. A spillbay discharge of 5,900 cfs produced skimming flows for submergences of 7-8 ft. As with the Type 2 Deflector, no satisfactory flow conditions were observed for spillbay discharges greater than 5,900 cfs. During higher discharges, the flow plunged at low submergences. As the tailwater elevation was raised, the flow conditions changed from an unstable nappe to the conditions where the nappe would ride up on the tailwater surface creating an undulatory surface with multiple standing waves and plunging flows in the vicinity of the baffle blocks and end sill. With higher tailwater elevations, the nappe overrode the deflector and plunged to the stilling basin floor.

15. Raised Stilling Basin. A shallow stilling basin is under design and testing in the Ice Harbor Sectional Model (Figure 7). The shallow basin reduces the occurrence of plunging flows because a strong hydraulic jump occurs at smaller discharges and the shallow depth (<20 ft at normal tailwater), reduces the effects of hydrostatic pressure on air-entrained flow. The sectional model will be used to determine the operational limits of the raised stilling basin, including its maximum discharge with acceptable in-basin energy dissipation, tailrace erosion with over-design flows, etc.

16. Application to other Projects. The results of deflector studies in the Ice Harbor model find direct application to John Day and other projects. The deflector design and performance criteria based on deflector submergence will be used to design and locate deflectors for the John Day spillway. Flow patterns observed in the model help explain the gassing characteristics of deflectors. Experimental work on the raised stilling basin will define its operational range.

17. Summary and Recommendations. Sectional models of four Snake and Columbia River projects are available at WES for experimentation related to dissolved gas concerns. The value of a physical model for assessing dissolved gas issues lies in flow visualization and design comparison. Plunging flow patterns indicate opportunity for air entrainment and gas absorption. Highly-turbulent surface flows with standing waves will likely result in surface aeration with plunging flows from which significant levels of atmospheric gases can be absorbed. Design or operational modifications that avoid these type of flow conditions should result in lower levels of total dissolved gas.

18. The sectional model of Ice Harbor was used to examine the flow patterns with the existing stilling basin and with several different deflectors. A 12.5-ft-long deflector with a 15-ft toe radius (similar to the Lower Granite deflector) was selected for detailed study. The performance characteristics were related to deflector submergence and spillbay discharge. "Skimming flow" in the stilling basin and tailrace was achieved for a narrow range of submergence. Undulant "rolling" surface waves and with associated plunging flow resulted for discharge above 6,000 cfs per bay; skimming flow could not be established. For conditions outside of the "skimming flow" envelope, the flow was

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either undulant with rolling surface waves and plunging flows (high tailwater and deep submergence) or plunged into the stilling basin at the baffle blocks (low tailwater and shallow submergence). Operation outside of skimming flow will likely cause elevated dissolved gas levels because of surface air entrainment and the vertical circulation cells under the wave action.

19. An elevated stilling basin, similar to The Dalles stilling basin, is being tested for its hydraulic performance limits. Because of the shallow depth and relative short length, the basin's performance at extremely high flow, such as the probable maximum flood, will likely be inadequate. Model tests will determine the operational limit for adequate energy dissipation and the potential for tailrace erosion during higher discharges.

20. The key questions for resolution regarding the "best" alternative, i.e., deflectors or raised stilling basin, are: "Does a deflector give a sufficient operating range for the expected discharge and tailwater elevation? Is the expected operating range much larger than the extent of "skimming" flow conditions? If the anticipated range is narrow, then the deflector is the attractive alternative. If the range is larger, then the elevated stilling basin should be the stronger candidate.

Steven C. Wilhelms  
Engineer  
Locks, Reservoirs, and Fisheries  
Hydrodynamics Branch

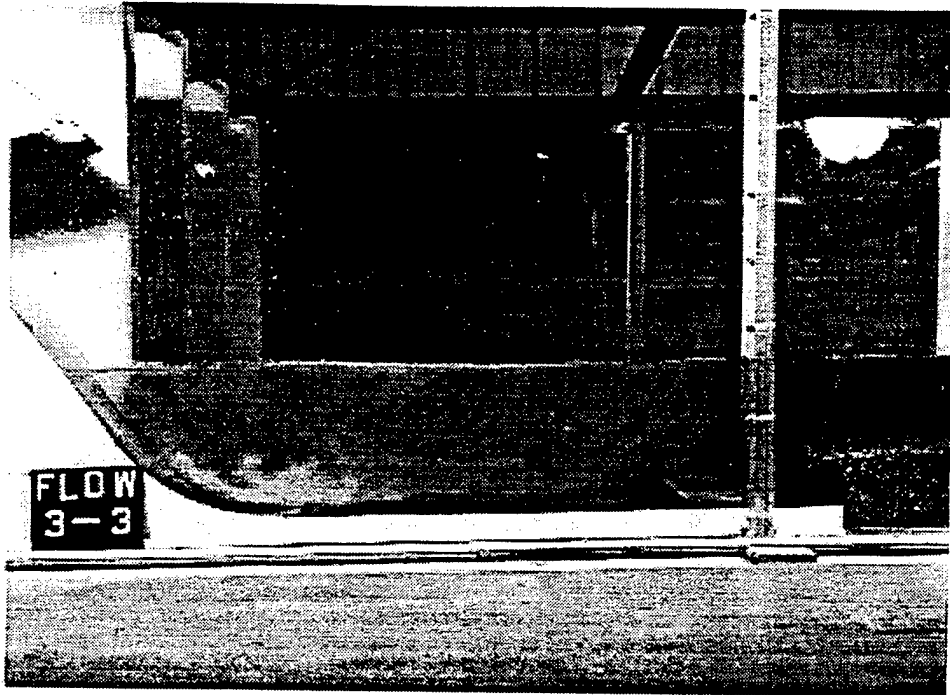
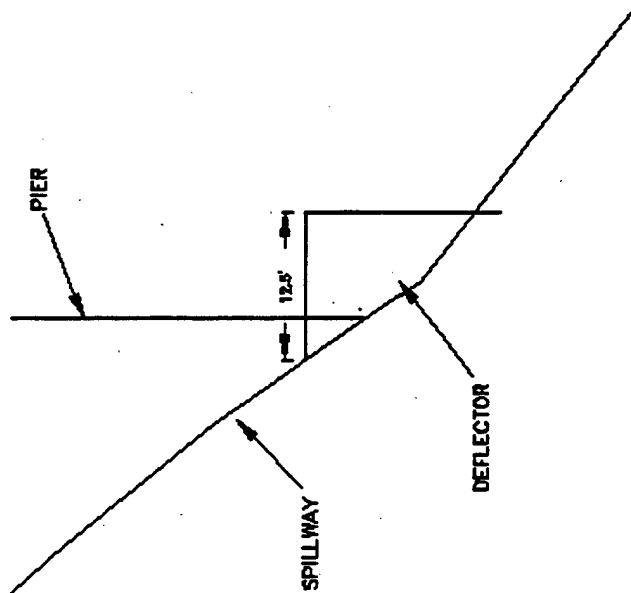
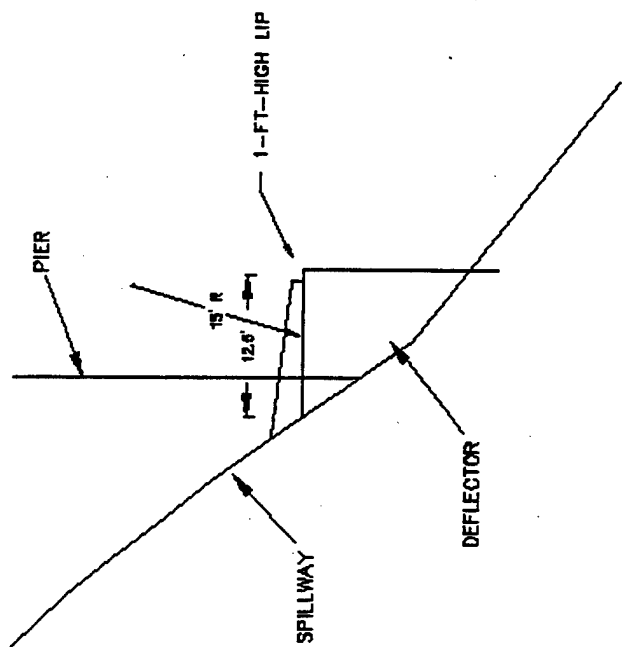


Figure 1. Ice Harbor Spillway Flow Patterns, Discharge = 5,700 kcfs/bay,  
Tailwater El = 344 ft



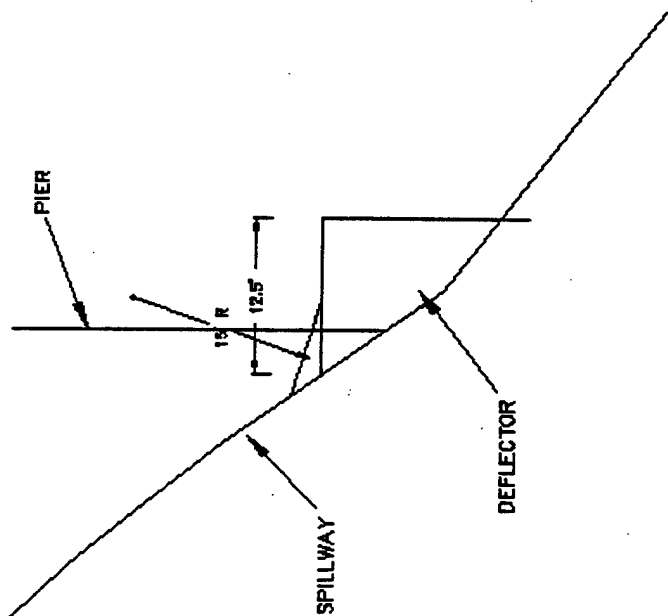
ICE HARBOR SECTION  
TYPE 1 FLOW DEFLECTOR  
PROFILE VIEW

Figure 2. Cross-section of Type 1 Flow Deflector



ICE HARBOR SECTION  
TYPE 1 FLIP LIP  
PROFILE VIEW

Figure 3. Cross-section of Type 1 Flip Lip



ICE HARBOR SECTION  
TYPE 2 FLOW DEFLECTOR  
PROFILE VIEW

Figure 4. Cross-section of Type 2 Flow Deflector

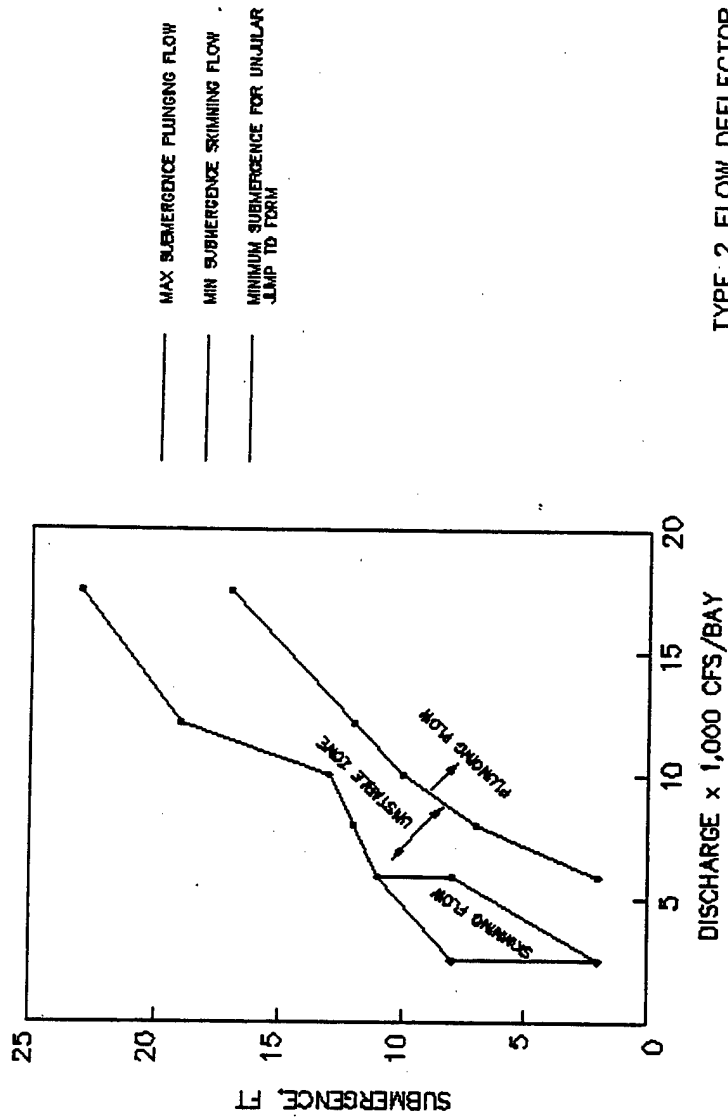
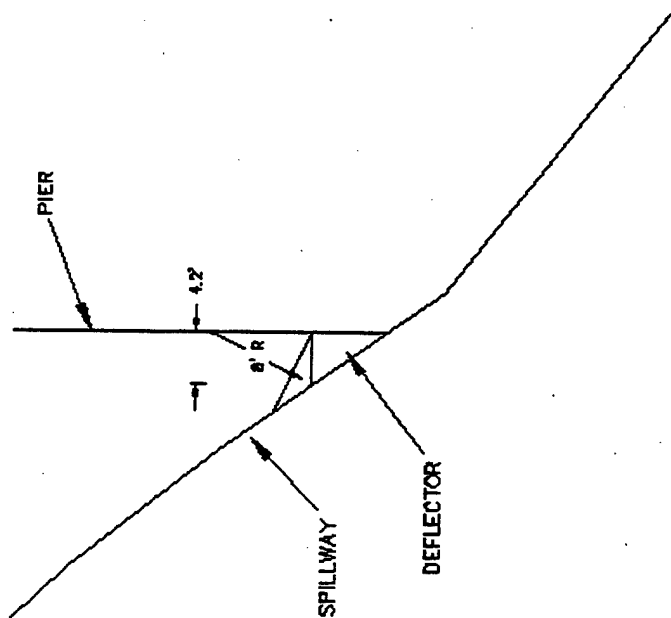
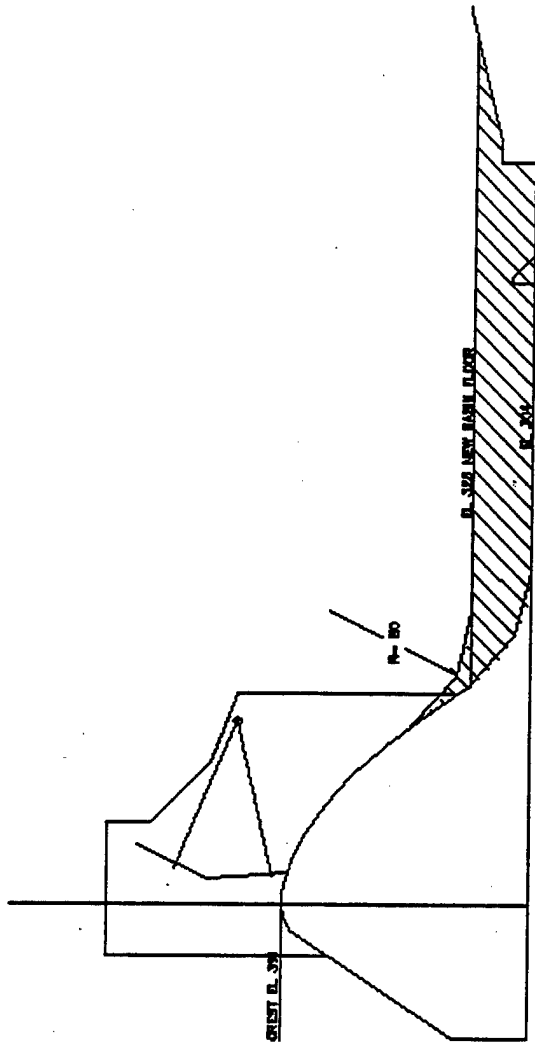


Figure 5. Hydraulic Performance of Type 2 Flow Deflector as a Function of Submergence



ICE HARBOR SECTION  
TYPE 3 FLOW DEFLECTOR  
PROFILE VIEW

Figure 6. Cross-section of Type 3 Flow Deflector



BASIN RAISED TO ELEVATION 325

Figure 7. Cross-Section of Raised Stilling Basin



DEPARTMENT OF THE ARMY  
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS  
3909 HALLS FERRY ROAD  
VICKSBURG, MISSISSIPPI 39180-6199

REPLY TO  
ATTENTION OF

CEWES-HS-S (1110-2-1403b)

18 March 1996

MEMORANDUM FOR COMMANDER, U.S. Army Engineer District, Walla Walla,  
ATTN: CENPW-EN-DB/Rick Emmert, 201 N Third Street,  
Walla Walla WA 99362-1876

SUBJECT: Data Report Ice Harbor Section Study

1. The purpose of this letter is to transmit data obtained from the subject model with and without various size and shape flow deflectors placed on the spillway. Enclosures 1-9 are photographs of flow conditions with no deflector on the spillway. Pertinent information is provided on the back of each photograph. These photographs show a plunging flow jet which generally conforms to the spillway shape and transports air bubbles to the full depth of the stilling basin. While this is an effective means of dissipating energy in the basin, the air bubbles are subjected to very high hydrostatic pressures at prototype depth, which is the major cause of gas absorption to supersaturated levels. The purpose of flow deflectors is to reduce or eliminate the plunging flow and transport of air bubbles to depth.
2. The type 1 flow deflector is shown in encl 10. It was 12.5 ft long and similar to the deflector developed at the Bonneville Hydraulics Laboratory. The results of experiments with the type 1 deflector showed the spillway flow jet sprayed off the deflector causing large highly-aerated waves to form in the basin during most flow conditions. The associated turbulence from these waves transported air bubbles to depth because of the plunging nature of the flow induced by the waves.
3. As a result of the hydraulic performance of the type 1 flow deflector, the type 1 flip-lip was developed (encl 11), consisted of a 12.5-ft-long deflector with a 15-ft toe radius at the spillway and a 1-ft high lip at the downstream end of the deflector. The toe radius reduced the effects of nappe impact on the deflector, however, the flip lip launched the flow at normal tailwater elevations and the aerated nappe plunged into the stilling basin in the vicinity of the baffle blocks entraining air and producing undesirable flow conditions.
4. The type 2 flow deflector (encl 12) was similar to the deflector installed at Lower Granite Dam: 12.5 ft long with a 15-ft toe radius at the spillway which acted as a fillet to smooth the nappe transition between the spillway and the deflector. Experiments conducted with this design showed significant improvement for flows of up to 5,900 cfs per bay compared to the other designs. Experimenting with flows of 2,500, 4,200, and 5,900 cfs per bay showed that at very low tailwater elevations, the underside of the nappe would be aerated and the flow would plunge to the stilling basin floor (encl 13). This condition entrained large volumes of air and transported air bubbles to depth in the stilling basin and tailrace area. As the tailwater elevation was increased, the venting of the nappe was inconsistent and produced an unstable condition with periods of the flow alternately plunging to the stilling

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basin floor or attempting to ride the surface of the tailwater (encl 14). When the tailwater elevation was sufficient to prevent aeration at the downstream edge of the deflector, the flow jet remained along the surface of the tailwater and produced the desired "skimming" flow conditions (encl 15). With higher submergences, the nappe would ride up on the downstream water surface forming an unjular jump resulting in large standing waves and plunging flows in the vicinity of the baffle blocks (encl 16). With high tailwater elevations, a hydraulic roller would form at the deflector (encl 17), and with extremely high tailwater, the nappe submerges resulting in a submerged hydraulic jump that was elevated off the stilling basin floor by the deflector.

5. Initial experiments were conducted with the type 2 deflector located at el 335 (minimum tailwater). An analysis of operating conditions at Ice Harbor Dam indicated that a deflector located at el 338 would better optimize the range of normal tailwaters for the skimming flow condition. Thus, experiments were conducted with the deflector installed on the model spillway at el 338. Photographs of flow conditions with the deflector located at el 338 are shown in encl 18-26. These photographs can be compared to encls 1-9, which show the same flow conditions without the deflector on the spillway. Enclosures 27 and 28 are plots of flow conditions with the type 2 deflector located at el 335 and 338, respectively. These plots define deflector performance as a function of submergence and spillbay discharge. Submergence is defined as the differential between tailwater and deflector elevation. A comparison of the plots shows that with the deflector located at el 338, a larger range of skimming flow conditions exists than with the deflector located at el 335, including a narrow band of flows at 8,000 cfs per bay.

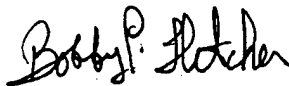
6. Experiments were also conducted to determine flow conditions with a smaller deflector (type 3, encl 29). A narrower band of satisfactory flow conditions was observed than with the type 2 deflector located at either el 335 or 338. With a spillbay discharge of 2,500 cfs, the skimming flow condition existed for submergences ranging from 1-4 ft. A spillbay discharge of 5,900 cfs produced skimming flows for submergences of seven to eight ft. As with the type 2 deflector located at el 335, no satisfactory flow conditions were observed for spillbay discharges greater than 5,900 cfs. During higher discharges, the flow plunged at low submergences. As the tailwater elevation increased, flow conditions changed from an unstable nappe to an undular jump with standing waves and plunging flows in the vicinity of the baffle blocks and end sill. With higher tailwater elevations, the nappe overrode the deflector and plunged to the stilling basin floor.

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6. If there are any questions or comments please contact  
Mr. John George (601) 634-3344.

FOR THE DIRECTOR, HYDRAULICS LABORATORY:



29 Encls

*for* JOHN F. GEORGE  
Acting Chief  
Hydraulic Structures Division

ENCLOSURES ARE NOT INCLUDED.

## **APPENDIX C**

**Excerpt from Appendix A - Section 1 of *Ice Harbor  
Spillway Deflectors, Letter Report*, (October 1994, preliminary)**

## 1.02. EFFECTIVENESS OF DEFLECTORS IN REDUCING DISSOLVED GAS SUPERSATURATION.

Lower Monumental Dam's spillway is very similar to the Ice Harbor spillway, and there is dissolved gas data both before and after spillway deflectors were added at Lower Monumental. A close evaluation of data collected from 1969 to 1971 below Lower Monumental Dam was completed. Data from this period was selected for comparison purposes if the sample site was judged to be representative of the current data collection site and also had a forebay dissolved gas level measurement taken as well. These data points were compared to data collected in 1992 and 1993. Data from 1992 and 1993 were selected for comparison with the pre-deflector period if the spill level and forebay dissolved gas level were found to be similar. Comparison of this data, as described below, is being used in this report to estimate what the effectiveness of spillway deflectors would be if constructed at Ice Harbor Dam. This estimate is further supported by data collected by the Lower Monumental tailwaters monitoring station during May of 1994. This station is on the south shore and detects TDG pressures in the water that has passed through spillbay 1; or spillbay 2 when spillbay 1 is closed. With spillbay 1 open two stops (a stop is a gate-setting increment), TDG levels of 125 percent were recorded. When the spill pattern was altered (to reduce TDG supersaturation) to zero stops on bay 1 and two stops on bay 2, the resulting TDG levels recorded were approximately 116 percent of saturation; a reduction of 9 percent.

Several tests have attempted to determine the efficacy of the spill deflectors at Lower Monumental Dam. Ebel *et al.* (1973) reported a 20 percent reduction of nitrogen supersaturation in the tailrace based on levels determined from a prototype deflector equipped bay (with dentates) and a standard non-deflector bay. In Park *et al.* (1976) samples were taken in the stilling basin below Lower Monumental Dam at each of spillways. They also postulated that TDG supersaturation would have been 10 to 20 percent higher at Lower Granite Dam had there not been spill deflectors installed before operation.

### a. Methods.

We experienced several problems selecting possible approaches for evaluating the efficacy of spill deflectors for this paper. First, we need to address concerns we had regarding the accuracy of the data because of the differing measurement methodologies used 20 years ago and the dependence of them on the expertise of the instrument operators. After comparing their results with satumeter studies (Fickeisen *et al.* 1975), investigating the Van Slyke and gas chromatography methods, and comparing several like data points, we determined the data was accurate enough for purposes of this report. Another problem was that we needed pre- and post-deflector installation dissolved gas measurements during comparable project operations. The primary problem in comparing before and after data was that the older data was expressed as dissolved nitrogen in ml/L and dissolved oxygen in mg/L. Tailwater dissolved gas data from measurements made between 1969 and 1972 were downloaded from the Portland Office CROHMS database. These data were collected using either the Van Slyke or gas chromatography methodology, which measures nitrogen gas volume instead of pressure. Therefore, it was

necessary for us to convert the data into TDG values using the mathematical relationship presented below.

$$TGP = \left[ \frac{\frac{O_2}{BCO}(0.5318) + \frac{N_2}{BCN}(0.6078) + Vp}{BP} \right] * 100$$

Where:

- TGP is the total gas pressure
- O<sub>2</sub> is the concentration of dissolved oxygen in mg/l by Winkler titration
- N<sub>2</sub> is the concentration of dissolved N<sub>2</sub> in ml/l by the Van Slyke or GC method and converted to mg/L
- Vp is vapor pressure from the program with barometric pressure and temperature as variables
- BCO is the Bunsen coefficient for oxygen
- BCN is the Bunsen coefficient for nitrogen
- BP is the barometric pressure

Common Sensing Tensionometers were used to collect the more recent dissolved gas data from the Snake River projects. These instruments detect TDG pressure and barometric pressure to yield percent of TDG saturation as a measurement. Data used in this study were collected from the telemetry station in the forebay at Lower Monumental (Station 1018) and automated data logging station 1 mile downstream on the left bank. The data from the forebay station is transmitted via GOES satellite to the CROHMS data base in Portland. We downloaded these discharge data from the CROHMS data base directly. Data from the deployed "non-reporting" logging stations (Ice Harbor and Lower Monumental tailwaters) were available in-house.

Data points from the 1969 through 1972 pre-deflector data were compared to like 1992 and 1993 post-deflector data points. Data was sorted by its site and by the percentage of supersaturation found in the forebay. Included were the spill discharge and the calculated difference between the forebay and tailrace. We then selected a data point from one of the test groups or CROHMS set was reflected. The like data point from another sensor station or data grouping must have been within the same day and operations hour to be included in the data set.

Although there was a large number of data points, data points with forebay TDG, spill discharge, and tailrace parameters were only about 10 percent to 15 percent of the entire data set. Data analogs to the 1969 to 1971 set were selected from the 1992 and the 1993 data. The following criterion was used to select data points:

- Step 1. Select the sites in the data that best represents our current sampling regime.
- Step 2. 1969-1972 data sets with forebay and tailrace data were compared directly to analogs from 1992 or 1993 if the percentage of forebay supersaturation was within 1.5 percent and the spill discharge was within 5 kcfs in analogs when spill was below 75 kcfs. When spill was greater than 75 kcfs available data points with similar spill discharge, forebay TDG saturation, and tailwater TDG levels were used.
- Step 3. Each 1969 through 1971 data point had multiple analogs. The mean of the differences between the forebay and the tailwater TDG saturation (TDG production) was compared with the 1969 through 1971 data point. This comparison yielded a difference that represents the improvement (reduction) in the TDG supersaturation production provided by installation of spill deflectors.

b. Results of the 1969 to 1971 Pre-Deflector Data Compared to the 1992 and 1993 Post-Deflector Data.

The results from the 1969 through 1971 analog comparisons are expressed in table 1-2. This comparison resulted in a mean of 9.4-percent decrease in TDG production after spill deflectors were installed at Lower Monumental Dam. The decrease of TDG production ranged from 0.6 percent to 14.9 percent between 2.9 kcfs and 60 kcfs with a mean of 7.7 percent. The decrease of gas production ranged from 8.5 percent to 13.5 percent between 61 kcfs and 100 kcfs with a mean of 11.0 percent. The decrease of gas production ranged 2.7 percent to 13.2 percent with a mean of 9.0 percent at 100 kcfs and above range. The reduction in the TDG production from this data comparison is shown in Figure 1-4 below. The conclusion drawn from this data comparison was that the spillway deflectors at Lower Monumental Dam reduced TDG production by 9.4 saturation percentage points.

Table 1-2. The 1969-1971 Data Sets Compared to the 1992-1993 Analogs with Average Total Dissolved Gas Supersaturation at Lower Monumental Dam.

Date of data	Q" Spill	Forebay percent Sat	Tailwater percent Sat	percent Diff	percent Reduction
69/6/5	81.1	114.8	137.9	23.1	
93/6/4	84.8	115.28	124.92	9.64	
			<i>93 Average</i>	9.64	13.5
69/6/17	20.1	105.5	128.9	23.4	
93/6/12	24.2	105.54	113.9	8.36	
93/6/10	24.3	105.54	114.25	8.7	
92/6/19	22.81	105.39	119.52	14.13	
92/6/3	20.71	105.61	125.19	19.59	
92/5/31	19.41	105.87	116.85	10.97	
			<i>92-93 Average</i>	12.35	11.1
69/7/1	44.2	107.1	140.9	33.8	
93/5/5	37.4	108.3	124.9	16.6	
			<i>93 Average</i>	16.6	17.2
69/7/15	14.1	115.9	121.8	5.9	
93/5/7	16.9	115.86	117.1	1.23	
92/5/28	14.2	115.93	113.27	-2.65	
93/5/9	12.7	116.07	115.4	-0.67	
93/6/14	10.7	116.09	117.53	1.44	
93/5/31	16.7	116.15	112.43	-3.71	
93/5/13	10.5	116.18	118.31	2.13	
93/5/31	14.2	116.48	113.7	-2.76	
			<i>93 Average</i>	-0.71	6.6
70/4/21	12.6	123.3	130.5	7.2	
93/5/26	10.6	122.62	119.72	-2.9	
			<i>93 Average</i>	-2.9	10.1
70/5/19	111.1	137.7	134.2	-3.5	
93/5/19	112.4	139.9	133.4	-6.5	
93/5/19	95.3	139.5	133.5	-5.9	
			<i>93 Average</i>	-6.2	2.7

Table 1-2. (continued)

Date of data	Q" Spill	Forebay percent Sat	Tailwater percent Sat	percent Diff	percent Reduction
70/6/23	70.8	138.4	136.9	-1.5	
93/5/20	87.2	138.33	128.31	-10.01	
			<i>93 Average</i>	-10.01	8.5
71/1/26	45.3	117	128.8	11.8	
93/5/27	44.5	117	116.7	-0.27	
93/5/28	39.8	117	111.54	-5.54	
93/5/27	44.6	117.15	116.43	-0.72	
93/5/28	39.8	117.24	111.49	-5.75	
			<i>93 Average</i>	-3.07	14.87
71/2/22	5.6	120	124.5	4.5	
93/5/6	6.3	120.19	117.7	-2.45	
93/5/6	6.3	120.45	118.4	-2.04	
93/5/10	4.5	120.95	115.64	-5.31	
			<i>93 Average</i>	-3.26	7.76
71/4/6	28.7	128.8	132.4	3.6	
93/5/25	27.8	128.3	125.04	-3.29	
93/5/19	32.4	129	124.97	-4.11	
93/5/25	27.8	129.2	125.2	-3.99	
			<i>93 Average</i>	-3.79	7.39
71/4/20	27.8	131.8	131	-0.8	
93/5/25	27.7	131.55	125.39	-6.15	
93/5/18	24.2	131.68	129.77	-1.91	
			<i>93 Average</i>	-4.03	3.23
71/5/4	128.1	130.1	137.9	7.8	
93/5/21	100.4	131.46	126.39	-5.07	
93/5/9	122.4	131.81	126.13	-5.68	
			<i>93 Average</i>	-5.37	13.17
71/5/18	110.7	128.1	136	7.9	
93/5/17	121.4	128.32	124.4	-3.89	
			<i>93 Average</i>	-3.89	11.79
71/6/1	139.3	133.8	135.1	2.7	
93/5/19	122.4	131.81	126.13	-5.68	
			<i>93 Average</i>	-5.68	8.38
71/7/13	8.7	109.7	116.1	6.4	
93/6/9	5.2	109.6	110.04	0.43	
93/6/9	5.4	109.21	111.08	1.87	
93/5/5	5.3	110.21	110.79	0.58	
92/6/24	8.9	109.7	111.19	1.48	
			<i>92-93 Average</i>	1.09	5.31

c. Discussion.

(1) Discussion of the Results.

Our results suggest that in the low to medium discharge, spill deflectors retard TDG production. All available data from 1967 through 1975 was evaluated. The data from 1972 to present contains data that is not completely without- spill- deflector data. The data points in table 1-2 were the points where there was a complete set of data. Since this was the only complete pre-deflector data set, we considered the information in table 1-2 to best approximate the non deflector dam.

We did not consider the 1972 data representative for several reasons. We were unable to obtain spill records, stop settings, and general operational information to determine discharge. Since there was a spill deflector in place at Lower Monumental Dam in 1972, without the operations data we are unable to determine what effect the spill deflectors had on the total supersaturation in the forebay. The 1972 spill deflector test data did not show the benefits of multiple deflectors. Additionally, the 1972 test data did not reflect the benefits based on a wide range of spill discharge, forebay saturation, and did not take into account the full powerhouse capacity.

The result of this study suggests that the spill deflectors may provide an average of 8 percent to 10 percent reduction in TDG supersaturation production over a range of spill between 0 and 140 kcfs at Lower Monumental Dam (Figure 2). The 1992 and 1993 data had operations records that suggest spill deflectors are most effective in reducing TDG supersaturation when the spill is spread over the entire array of spill gates. Even with spill deflectors in place, a decrease of 10 percent subtracted from the 130-percent forebay TDG (common during high spill years), supersaturation is still above the EPA criterion and the Washington State water quality standard of 110 percent.

The comparison of forebay to tailrace TDG data in recent years (with deflectors) shows a consistent reduction in TDG supersaturation over the spillway at Lower Monumental when forebay TDG levels are elevated. This may suggest that Lower Monumental Dam's spillway may be a "treatment center" for TDG supersaturation. This could occur if the contact with the atmosphere realized as the water passes over the spillway allows rapid dissipation of TDG supersaturation, and the TDG pressure that was measured in the forebay is not reproduced in the stilling basin. Current research in this area is insufficient and further work must be done.

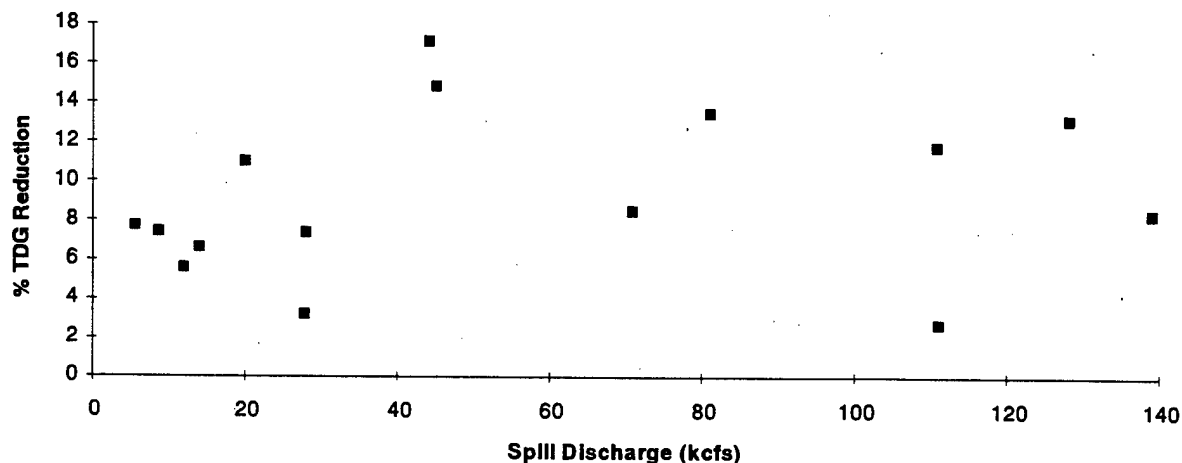


Figure 1-4. TDG production decrease as calculated using data from table 1-2, where the benefit of spill deflectors expressed as percent TDG Reduction is plotted against spill discharge (kcfs) at Lower Monumental Dam.

## (2) Review of Previous Efficacy Studies.

We analyzed the best data we could obtain to revisit the previous efficacy tests. The 1972 "Project Flip-lip" test (Ebel *et al.*, 1973) resulted in a 13.7 percent reduction of TDG production with a dentated deflector compared to a standard bay at Lower Monumental Dam. This test corroborated our findings. When we reevaluated the 1975 data (Park *et al.* 1976) we were unable to determine what had been evaluated based on the data available. In their discussion they stated samples were taken from 25 to 27 March 1975 during 5 separate tests. During the tests, six deflector bays spilled 4.6, 9.7, 14.9, and 20 kcfs per bay (tests 2 to 5). During the test temperature remained at 6° Celsius and forebay supersaturation averaged about 108.7 percent, while the tailrace supersaturation ranged from 112.3 to 123.7 percent N<sub>2</sub> (not TDG). These results indicated that there was less benefit than anticipated from the 1973 data. After reviewing several other data sets and converting the old data into TDG values, we believe that sample size was too small to be conclusive and there was error in the test design

An extensive N<sub>2</sub> analysis was made of McNary Dam (Park *et al.*, 1977). At McNary Dam, 18 of the 22 spillways were installed with deflectors. Tests designed to evaluate the effects of the 18 spill deflectors investigated a wide range of spill patterns. These included: 1) single vs. multiple bay discharges; 2) light, moderate, and heavy spill discharges; 3) uniform vs. non-uniform gate discharges; and 4) low and high N<sub>2</sub> in the forebay. They reported a 10 percent to 16 percent reduction (N<sub>2</sub> not TDG) benefit from the deflectors. They reported that a 249-kcfs

spill resulted in a 128-percent  $N_2$  tailrace supersaturation with deflectors in place, compared with commonly occurring 140 percent at discharges around 250 kcfs prior to the installation of deflectors. This compares well with our estimate of probable benefits of spillway flow deflectors at Ice Harbor Dam and with what was found at Lower Monumental Dam.

d. Conclusion--Estimation of Spill Deflector TDG Benefit at Ice Harbor Dam.

Predicting TDG benefit at Ice Harbor is difficult based on Lower Monumental data. The Ice Harbor stilling basin, although generally similar, is different from Lower Monumental. The length of the Ice Harbor stilling basin is 168 feet compared to Lower Monumental's 180 foot stilling basin. The real question is: How effective will deflectors be if constructed at Ice Harbor? To extrapolate the effectiveness of the spillway deflectors at Lower Monumental to Ice Harbor, the spillway stilling basin depth parameter was used since the second largest influence on the level of TDG production is probably the depth of plunge that the entrained air experiences. In general, a reduction in the stilling basin depth will reduce to some degree the potential for entrained air to go into solution. The tailwater elevation at Ice Harbor Dam is largely dependent on the river discharge. Thus the stilling basin's depth is also dependent on the river discharge. Ice Harbor's stilling basin depth compared to Lower Monumental's for the same river discharge is approximately 70 to 90 percent of the stilling basin depth at Lower Monumental, depending on the selected river discharge. Therefore it has been estimated that the effectiveness of spillway deflectors at Ice Harbor would be 70 to 100 percent of the mean 9.4 percent saturation reduction experienced at Lower Monumental. This leads to estimated TDG supersaturation reduction potential of approximately 7 to 10 percent saturation. The potential should be further modified based on the number of bays retrofitted with deflectors. If deflectors were only constructed on the center six bays, then only 60 percent of the spill discharge would be affected (depending on spill pattern) as compared with 80 percent of spill passing over deflector fitted bays at Lower Monumental. Consequently, a reduction potential of at least 5 percent and as great as 10 percent is likely to be achieved when spill discharge is within the spillway deflector's skimming flow discharge range designed for Ice Harbor Dam.

## **APPENDIX D**

### **Correspondence**



Reply To  
Attention Of:

DEPARTMENT OF THE ARMY  
WALLA WALLA DISTRICT, CORPS OF ENGINEERS  
201 NORTH THIRD AVENUE  
WALLA WALLA, WASHINGTON 99362-1876

June 12, 1996

Planning Division

Dear Interested Party:

Enclosed for your information are the signed Finding of No Significant Impact (FONSI) and comment letters response package for the proposed Ice Harbor Dam Spillway Deflectors project on the Snake River in Franklin and Walla Walla Counties, Washington. The signing of the FONSI completes the environmental review process for this project under the National Environmental Policy Act (NEPA). The comment letters package includes the three letters the Corps received on this project and the Corps' responses to the comments in the letters.

Should you have any questions or need additional copies of the FONSI or the comment responses, please contact Ms. Sandy Simmons at 509-527-7265.

Sincerely,

A handwritten signature in cursive script, reading "Carl J. Christianson", is written over a horizontal line.

Carl J. Christianson  
Chief, Environmental Resources Branch

Enclosures

## **FINDING OF NO SIGNIFICANT IMPACT**

### **ICE HARBOR DAM SPILLWAY DEFLECTORS**

#### **FRANKLIN AND WALLA WALLA COUNTIES, WASHINGTON**

The Corps of Engineers proposes to modify the spillway of Ice Harbor Dam by constructing deflectors on up to ten of the spillbays and extending one or both training walls. The dam is located on the lower Snake River at River Mile 9.5, near Pasco, Washington. The purpose of the deflectors is to reduce the amount of dissolved gas produced as river flows are passed through the dam spillway. High concentrations of total dissolved gas (TDG) can injure or kill juvenile and adult salmon, as well as resident fish and other aquatic organisms. The need for TDG abatement is of immediate concern to the region because of declining salmon populations and the listing of three Snake River salmon stocks (spring/summer chinook, fall chinook, and sockeye) as either threatened or endangered under the Endangered Species Act. In their March 1995 Biological Opinion on Operation of the Federal Columbia River Power System, under Reasonable and Prudent Measures Intermediate Term Action No. 18, the National Marine Fisheries Service requested that spillway modifications for gas abatement at Ice Harbor Dam be completed as soon as possible, contingent on the results of TDG abatement evaluations in 1995 and 1996. The Corps proposes to construct eight deflectors in 1996/1997 and the remaining two deflectors and the training wall extension(s) in 1997/1998 to comply with NMFS' request.

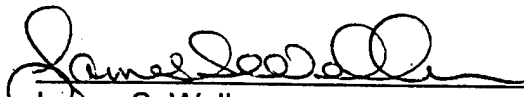
The Corps evaluated several other alternative methods of reducing TDG. These included modifying the stilling basin, raising the tailrace, making operational changes in the spill pattern, and eliminating voluntary spill of water for fish passage. These alternatives were removed from further consideration because they are still being investigated as part of the on-going gas abatement studies and may take between 4 and 10 years to implement. The Corps identified only one alternative, spillway deflectors, that would provide meaningful reduction in TDG and could be implemented in time for the 1997 outmigration. Therefore, constructing and operating the spillway deflectors is the Corps' selected action.

Construction and operation effects of the proposed spillway deflector project are addressed in the project environmental assessment. Effects of the facilities are largely focused on impacts to the aquatic environment. Construction of the spillway deflectors would have minimal impacts on aquatic resources in the vicinity of the dam. No important fish habitat would be disturbed by the construction and fish and other organisms in the river would easily avoid the construction activities. The starting date for the in-water construction has been pushed back from August 1, 1996 to September 1, 1996 to allow for spill for juvenile fall chinook passage during August. Operation of the spillway deflectors is expected to decrease TDG when water is being spilled, which would improve in-water conditions for salmon as well as other aquatic

organisms. The Corps has estimated that installing deflectors of at Ice Harbor Dam could possibly reduce dissolved gas supersaturation by up to 5- to 10-percent for spills flows up to 60,000 cubic feet per second (cfs).

This project has been coordinated with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Washington Department of Fish and Wildlife, other concerned state and Federal agencies, tribes, and the public. The project is in compliance with all applicable laws and regulations. In view of the information provided by these sources, the environmental assessment, and comment letters, I find that the proposed action would not result in significant impacts and that an environmental impact statement is not required.

DATE: 13 Jun 96

  
James S. Weller  
Lieutenant Colonel, Corps of Engineers  
District Engineer



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 10  
1200 Sixth Avenue  
Seattle, Washington 98101

Reply To  
Attn Of:

ECO-088

16 May 1996

Department of the Army  
Walla Walla District, Corps of Engineers  
ATTN: Chief, Environmental Resources Branch  
201 North 3rd Avenue  
Walla Walla, Washington 99362-1876

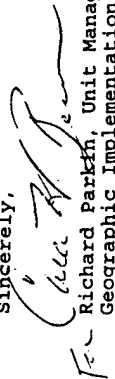
RE: Environmental Assessment and Draft Finding of No Significant  
Impact, Ice Harbor Dam Spillway Deflectors Project

Dear Mr. Mettler:

The Environmental Protection Agency (EPA) has conducted a review of the above referenced Environmental Assessment (EA). The proposed project was developed to reduce the amount of total dissolved gas (TDG) produced at Ice Harbor dam; thereby enhancing survival of adult and juvenile migrating salmon. Although the EA clearly describes the project's relation to TDG, it does not provide an adequate discussion of other water quality parameters as identified in state water quality standards. Parameters such as temperature are critical to any discussion of long-term salmonid survival. As such, the EA should evaluate project construction and operation in relation to all appropriate water quality parameters.

If you have any questions regarding EPA comments, please feel free to contact Cara Berman at 206/553-6246.

Sincerely,

  
Richard Parkin, Unit Manager  
Geographic Implementation Unit

cc: Sally Brough, EPA

Response to Environmental Protection Agency letter dated May 16, 1996

The Environmental Assessment (EA) did address all applicable water quality parameters for this project. The Corps discussed water quality concerns with the Washington Department of Ecology and the Washington Department of Fish and Wildlife. The only issues of concern identified by these agencies and the Corps were the amount of turbidity caused by construction activities and the proper handling of water that had been in contact with wet concrete. Both of these issues were discussed in the EA. The Corps did not address water temperature in the EA because it was not identified as an issue. Construction and operation of the spillway deflectors and training wall extension(s) would have no impact on water temperature in the Snake River.

UNITED STATES DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
NATIONAL MARINE FISHERIES SERVICE  
ENVIRONMENTAL & TECHNICAL SERVICES DIVISION  
525 NE Oregon Street  
PORTLAND, OREGON 97232-2737  
503/730-3400 FAX 503/730-3435



F/NW03

MAY 24 1995

Lt. Col. James R. Weller  
Walla Walla District  
Corps of Engineers  
201 North Third Avenue  
Walla Walla, Washington 99362-1876

RE: Proposed Implementation of RPA #18 - Ice Harbor Dam Spill  
Deflector Installation

Dear Colonel Weller:

This responds to your April 16, 1996, letter to J. Wyland requesting coordination with the National Marine Fisheries Service (NMFS) regarding installation of spill deflectors at Ice Harbor Dam. This action is required of the Corps of Engineers (COE) under Measure VIII.A.18 of the Reasonable and Prudent Alternative (RPA) in the March 2, 1995, Biological Opinion regarding operation of the Federal Columbia River Power System (1995 Biological Opinion). This measure states:

"The COE shall develop and implement a gas abatement program at all projects with appropriate structural modifications. The program shall include spilling basin and spillway modifications to reduce gas supersaturation at Ice Harbor and John Day Dams as soon as possible, contingent on the results of facility gas abatement evaluations in 1995 and 1996..."

NMFS' response follows the "Framework for Implementing and Modifying Actions in the 1995 FCRPS Biological Opinion" (Framework), which was attached to the April 28, 1996, letter from R. Fuhrman (COE) to W. Stelle (NMFS). Installation of spill deflectors at Ice Harbor Dam was listed as an action in the 1995 Biological Opinion for which additional information is needed to determine if the particular implementation is consistent with the opinion's objectives. Your April 16 letter provides the information needed by NMFS to determine that consistency. As stated in the Framework, our determination is based upon two criteria:

"...(1) is the action likely to gain significant relevant technical information needed for 1999 decisions concerning major system structural modifications for the long term, or, alternatively, is the action one that will provide survival benefits needed in the near term (prior to completion of long term actions); and (2) is the action designed to



2

minimize adverse effects associated with its implementation and operation?"

This action satisfies the first criterion, because it is an intermediate-term action to improve survival in the 1995 Biological Opinion (p. 124). The implementation plan proposed by the COE meets or exceeds the survival benefits anticipated in the 1995 Biological Opinion, if construction can be completed according to the proposed schedule, because installation of eight spillway deflectors by March 1997 is not required. RPA 18 calls for this action "as soon as possible," rather than by a specific date. We appreciate the efforts of the COE, which have led to an expedited schedule for implementation of this action.

With respect to the second criterion, the proposed action does not appear to minimize adverse effects associated with its implementation. The most serious adverse effect in the proposal is cessation of spill during the month of August. Provision of spill during August to increase dam passage survival is a specific requirement of RPA 4 in the 1995 Biological Opinion:

"During the fall chinook migration season (June 21 to August 31 in the Snake River and July 1 to August 31 in the Columbia River) the COE shall spill at all non-collector projects to achieve a fish passage efficiency target of 80%."

Page nine of your April 18 letter provides reasonable estimates of the parameters necessary to estimate effects of ceasing spill during the month of August. Using these estimates and a range of possible August flows, survival of juvenile Snake River fall chinook salmon arriving at Ice Harbor Dam is expected to be reduced 3-7% if spill is curtailed (Attachment 1). While your letter correctly points out that only a proportion of the total outmigration will be affected by the impaired passage conditions, this still represents a significant number of individual mortalities (e.g., 1% mortality of the estimated outmigration arriving at Lower Granite Dam is 605 fish).

Our primary concern is that this is an avoidable source of mortality because another implementation schedule is possible. NMFS requests that you delay in-water work required for installation of spillway deflectors until September 1, or an alternative date set by the Technical Management Team if the migration rate is faster than expected. We believe that the negative consequences of this schedule change are less than the benefits that will be provided by August spill.

First, in spite of the optimistic schedule included in your proposal, presentations by your staff at System Configuration Team (SCT) meetings indicated that there is no guarantee that all eight spill deflectors can be constructed prior to the 1997

spring migration, even if work begins in August. For instance, if the coming winter is similar to last year's, it would be nearly impossible to complete construction on schedule. Uncertainty in the construction schedule dictates that it is more prudent to guarantee a known survival benefit this summer than to forgo it for an uncertain benefit next spring. Also, because discussions with your staff indicate that it is reasonable to assume that at least six of the eight spill deflectors can be constructed by spring 1997 with a September 1 start date, decreased survival of juvenile Snake River spring/summer chinook during 1997 as a result of incomplete installation is expected to be minimal.

Second, discussions between your staff and the SCT do not rule out construction of eight spill deflectors by spring 1997, even with a September 1 start date. It may be possible to assign more personnel than previously anticipated or to take other steps to meet the original completion schedule. We have great faith in the technical ability of the COE and its contractors to meet this schedule.

Third, effects of incomplete installation on adult passage are expected to be minimal. It is likely that if construction proceeds from the central spill bays towards the ends, a spill pattern that will not impede adult passage can be achieved. We note that physical modeling indicated that neither six-bay or eight-bay conditions are ideal for adult passage, and completion of training wall extensions for bays 1 and 10 (and possibly spill deflectors in those bays) will be necessary to complete spillway improvements at this project. Also, as stated earlier, there is no guarantee that all eight spill deflectors can be constructed on time even if August spill is curtailed.

In conclusion, it is NMFS' opinion that the proposed implementation plan is not consistent with the conclusions of the 1995 Biological Opinion because: (1) the proposed schedule is more ambitious than that required by RPA 18 - later implementation would still be consistent with the 1995 Biological Opinion; (2) the proposed schedule violates a specific term of RPA 4; (3) the proposed schedule will result in an avoidable 3-7% reduction in survival of those juvenile Snake River fall chinook salmon arriving at Ice Harbor Dam in August; and (4) an alternative implementation schedule will avoid the adverse effects listed above without incurring significant additional adverse effects. As stated in the framework, through this letter NMFS is notifying the COE that additional consultation under section 7 of the Endangered Species Act is required if the COE intends to pursue the proposed implementation plan. Additional information is not required prior to consultation.

If you have questions or require additional information, contact Bill Hevlin (503-230-5415) or Chris Toole (503-230-5410) of my staff.

Sincerely,

*Brian J. Brown*

Brian J. Brown  
Deputy Division Chief

cc: Chris Pinney - COE CENPW  
Rick Emert - COE CENPW  
SCT members

Enclosure

Attachment 1

# ICE HARBOR DAM PASSAGE SURVIVAL WITH AND WITHOUT AUGUST SPILL

## ASSUMPTIONS:

SPILL CAP	25.00 kcf/s
LOW FGE	0.33
HIGH FGE	0.50
NON-TURBINE SURVIVAL	0.98
TURBINE SURVIVAL	0.85
SPILL EFF.	1.00

(Assumes 24-hr spill to spill cap)

## LOW FGE SCENARIO:

FLOW	% SPILLED	% NOT SPILLED	% GUIDED	% GUIDED SPILLED	FPE = % SPILLED + (% NOT SPILLED * % GUIDED)	(1-FPE) = % THROUGH TURBINE	WITH-SPILL SURVIVAL	0-SPILL SURVIVAL	DIFFERENCE
30	0.83	0.17	0.06	0.89	0.89	0.11	0.97	0.89	0.07
35	0.71	0.29	0.09	0.81	0.81	0.19	0.96	0.89	0.06
40	0.63	0.38	0.12	0.75	0.75	0.25	0.95	0.89	0.05
45	0.58	0.44	0.15	0.70	0.70	0.30	0.94	0.89	0.05
50	0.50	0.50	0.17	0.67	0.67	0.34	0.94	0.89	0.04
55	0.45	0.55	0.18	0.63	0.63	0.37	0.93	0.89	0.04
60	0.42	0.58	0.19	0.61	0.61	0.39	0.93	0.89	0.04
65	0.38	0.62	0.20	0.59	0.59	0.41	0.93	0.89	0.03
70	0.36	0.64	0.21	0.57	0.57	0.43	0.92	0.89	0.03

-- WITH-SPILL SURVIVAL = [FPE \* NON-TURBINE SURVIVAL] + [(1-FPE) \* TURBINE SURVIVAL]  
 -- 0-SPILL SURVIVAL = [FGE \* NON-TURBINE SURVIVAL] + [(1-FGE) \* TURBINE SURVIVAL]

## HIGH FGE SCENARIO:

FLOW	% SPILLED	% NOT SPILLED	% GUIDED	% GUIDED SPILLED	FPE = % SPILLED + (% NOT SPILLED * % GUIDED)	(1-FPE) = % THROUGH TURBINE	WITH-SPILL SURVIVAL	0-SPILL SURVIVAL	DIFFERENCE
30	0.83	0.17	0.06	0.92	0.92	0.08	0.97	0.92	0.05
35	0.71	0.29	0.14	0.86	0.86	0.14	0.96	0.92	0.05
40	0.63	0.38	0.19	0.81	0.81	0.19	0.96	0.92	0.04
45	0.58	0.44	0.22	0.78	0.78	0.22	0.95	0.92	0.04
50	0.50	0.50	0.25	0.75	0.75	0.25	0.95	0.92	0.03
55	0.45	0.55	0.27	0.73	0.73	0.27	0.94	0.92	0.03
60	0.42	0.58	0.29	0.71	0.71	0.29	0.94	0.92	0.03
65	0.38	0.62	0.31	0.69	0.69	0.31	0.94	0.92	0.02
70	0.36	0.64	0.32	0.68	0.68	0.32	0.94	0.92	0.02

-- WITH-SPILL SURVIVAL = [FPE \* NON-TURBINE SURVIVAL] + [(1-FPE) \* TURBINE SURVIVAL]  
 -- 0-SPILL SURVIVAL = [FGE \* NON-TURBINE SURVIVAL] + [(1-FGE) \* TURBINE SURVIVAL]



DEPARTMENT OF THE ARMY  
WALLA WALLA DISTRICT, CORPS OF ENGINEERS  
201 NORTH THIRD AVENUE  
WALLA WALLA, WASHINGTON 99382-1878

Reply To  
Attention Of:

June 11, 1996

Planning Division

Jacqueline Wyland, Division Chief  
National Marine Fisheries Service  
Environmental and Technical Services Division  
525 N.E. Oregon Street, Suite 500  
Portland, Oregon 97232

Dear Ms. Wyland:

This letter responds to your May 24, 1996, coordination letter commenting on our proposed construction of flow deflectors at Ice Harbor Dam. Pursuant to the Reasonable and Prudent Alternative Intermediate Term Action No. 18 of the March 2, 1995, Biological Opinion on Operation of the Federal Columbia River Power System (BIOp), we recognize the BIOp requests spillway modifications for gas abatement at Ice Harbor Dam be completed "as soon as possible." Our interpretation of this request was to advance flow deflector design and construction to permit completion prior to the 1997 spring/summer chinook salmon outmigration.

Based upon coordination input from National Marine Fisheries Service (NMFS) staff, we changed the in-water activity start date from August 1, 1996 to September 1, 1996, in our Invitation For Bid/Solicitation For Construction (IFB/SFC) to construct deflectors in 8 of the 10 spillways at Ice Harbor Dam. The proposed closure of the spillway will occur from September 1, 1996 through March 15, 1997. The IFB/SFC with the revised date went out for bid on May 17, 1996. An Amendment to this IFB/SFC went out for bid May 31, 1996, with the following additions:

a. A requirement that the contractor construct pier nose extensions prior to any activity related to deflector construction. The contractor retains the option to develop and select the dewatering and forming scheme. Our requirement allows for the contractor to develop a single-bay dewatering scheme that should reduce the risk of additional harm to juvenile migrants in the event that an hydrologic event would force spill during construction.

-2-

b. A request that the contractor work 7 days per week and 24 hours per day in an attempt to increase the probability of completing eight deflectors prior to the 1997 juvenile outmigration.

c. Deflector construction in spillways two and nine are optional bid items determined by us. We have the right to exercise its option for construction in these bays based upon monitored contractor progress and hydrologic projections for flow and operating conditions.

d. Completion of deflectors in bays four, five, six, and seven by December 15, 1996. Completion of deflectors in bays three and eight by January 20, 1997. Completion of deflectors in bays two and nine by March 1, 1997, if we choose to exercise its option. The contractor then would have about two weeks of clean-up and demobilization to meet the scheduled completion date of March 15, 1997.

e. Additional language where we suggest the contractor should consider using more than one bulkhead system and drilling platform in an attempt to increase the probability of completing the proposed construction of eight deflectors by the scheduled completion date of March 15, 1997.

National Marine Fisheries Service should be aware that the revised IFB/SFC and its Amendment reflect that there is no guarantee on the part of our selected contractor to complete eight deflectors by March 15, 1997, although we will actively pursue an aggressive contractor to achieve a fully completed project by the original target date. We reiterate our biologically-related concerns about interim or long-term spill operations with a spillway configuration of less than eight deflectors versus the full eight deflector configuration. The concerns are based on the following considerations derived from physical model studies and field testing for total dissolved gas (TDG) supersaturation:

a. Operation of nondeflector bays adjacent to deflector bays have high influence on the TDG production dynamics and hydraulic conditions in the tailrace. Preliminary results from the Ice Harbor and John Day Dam general models for partial spillway installation of deflectors are discouraging for the development of suitable hydraulic conditions in the tailrace. Consistent with field testing data collected by the Waterways Experiment Station (WES), the creation of strongly unstable submerged lateral flow across the channel was observed in the hydraulic models. Submerged lateral flows transport aerated water that is supersaturated with gas due to plunging through nondeflected bays. We expect no measurable change in gassing or

degassing dynamics of this volume of water would occur with spill operations through a spillway with less than eight deflectors. If less than eight deflectors can be constructed in the September-March work window, the Technical Management Team or any other regional management body could not expect an interim spill cap during 1997 that would be greater than the 25 Kcfs that is presently used to control tailrace TDG to the 120 percent concentration allowed by the State's temporary water quality waivers.

b. Development of a suitable adult spill passage pattern will be required for Ice Harbor in the event fewer than eight deflectors are installed. The Ice Harbor 1:55 scale physical model demonstrated that adult ladder attraction conditions would be worse with six deflectors resulting in difficulty in developing a suitable interim pattern due to a relatively large amount of atmospheric air introduced to be plunged to hydrostatic pressure with depth. The chosen pattern would be implemented during the interim spill period of April 15 through September 1, 1997 (assuming construction of the remaining deflectors will begin September 1, 1997). Physical model studies performed during March and April of 1996, in preparation of the Feature Design Memorandum (FDM) No. 34, indicated additional deflectors may be installed in spill bays 1 and 10 without negatively impacting adult fish passage conditions. The installation of these deflectors may require training wall extensions between spillbays 9 and 10 and possibly between spillbays one and two. Preliminary model studies indicate a training wall extension between bays 9 and 10 may provide better than existing adult passage conditions downstream of the north spillway entrance either with or without a deflector in bay 10. Because of the accelerated schedule, it was not possible to address these items in the FDM. However, these modifications are currently being modeled and will be addressed in a supplemental letter to the FDM. If approved, construction of these additional modifications would require an extended in-water work window during September 1997 through March 1998. If the installation of all eight deflectors are not completed during the 1996-97 in water work window, the remaining deflectors would be installed during September, 1997 through March, 1998. This would likely impact the construction schedule for the proposed additional modifications, potentially resulting in lower annual smolt survival than expected and adult delay that could otherwise be avoided.

c. For future reference pertaining to analytical evaluations, single unit powerhouse minimum at Ice Harbor is 11 Kcfs per turbine under free-spin, no-load operation or 15-17 Kcfs under minimum load operation. This powerhouse operational constraint does not allow us to spill 25 Kcfs and operate a turbine unit when total river flow is less than 40 Kcfs. Adjusting the analysis in enclosure one of your letter, this powerhouse operational constraint lowers the WITH-SPILL SURVIVAL percentage estimates.

d. The biological evaluation in the FDM No. 34 (page 4-6) indicates no measurable net benefit to interim or long-term systemwide salmon survival with installation of flow deflectors at Ice Harbor Dam. The estimated increase in spill cap volume from 25 Kcfs to 45 Kcfs may increase the short-lived probability to exceed the 80 percent FPE target in the BiOp for a higher total river flow range while maintaining the 120 percent TDG. The incrementally small two to three percent projected survival due to this marginal increase in FPE could likely be canceled out by the moderate likelihood of a two to five percent increase in direct spill mortality (Johnsen and Dawley, 1974; Muir et al., 1995; Long et al., 1975). In addition to the direct spill mortality concern, possible delay of smolts may occur resulting in increased exposure to TDG supersaturation due to recirculation patterns created by the vertical rolling hydraulic conditions under higher spill discharges (i.e., the increase in reach travel time indicated in the NMFS PIT-tag analysis for 1995).

e. In the event of forced spill above the expected hydraulic capacity of the powerhouse (76 Kcfs with one turbine unit inoperable), all construction activity in the spillway must be terminated and abandoned until safe conditions resume. Turbine unit five is currently inoperable at Ice Harbor Dam and is scheduled to be inoperable through October 1996. A forced spill event would result in an unknown amount of delay in construction completion for any number of deflectors prior to the March 15, 1997, target date.

#### Effects

##### Juvenile

Biological Opinion on Operation of the Federal Columbia River Power System operations for juvenile passage beyond September 1, 1996, do not require voluntary spill at Ice Harbor Dam. Closure of the spillway from August 31, 1996, through March 15, 1997, would be consistent with fish passage operations guided by the BiOp.

##### Adults

Adult Snake River fall chinook salmon are likely to be minimally affected by the proposed in-water construction activities, although spill generally detracts from adult passage conditions. There is potential for some minor near-field delay in ladder approach and entrance during low river flows, but the implementation is scheduled beginning with the center bays and working outward toward the ladder entrances to minimize potential effects of construction activity disturbance through noise or other emissions.


A consequence of partial deflector construction would be uncertainty associated with mechanical and TDG-related effects to adult migrants of all salmonid stocks while operating for an entire fish passage season relative to passage delay. Resultant hydraulic conditions would not be optimal according to more recent knowledge gained from 1993-1995 dam operations with voluntary spill and physical model studies. Voluntary spill patterns for adult and juvenile salmon passage during the 1997 outmigration would be highly weighted toward the use of deflector spillways.

#### Summary

This letter is provided as a response to consultation with the NMFS for the proposed action of constructing flow deflectors in the centered spillways at Ice Harbor Dam. We believe the closure of the Ice Harbor spillway from September 1, 1996 through March 15, 1996, would be consistent with BiOp RPA measure 4 that requires the spill operation for achieving the FPE target and not jeopardize the continued existence of listed Snake River salmon stocks or adversely modify their critical habitat beyond those assumed impacts and risks considered by NMFS in their BiOp for 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years.

If you have questions or require additional information, please contact me or Mr. Chris Pinney, Walla Walla District, Fishery Biologist, at 509-527-7284. Mr. Jim Athearn, at 503-326-2835, remains the North Pacific Division's ESA coordinator.

Sincerely,

  
James S. Weiler  
Lieutenant Colonel, Corps of Engineers  
District Engineer



State of Washington  
**DEPARTMENT OF FISH AND WILDLIFE**

Mailing Address: 800 Capitol Way N • Olympia, WA 98501-1091 • (360) 902-2200, TDD (360) 902-2207  
Main Office Location: Natural Resources Building • 1111 Washington Street SE • Olympia, WA

May 20, 1996

Lonnie E. Mettler, Acting Chief, Environmental Resources Branch  
Department of the Army  
Walla Walla District, Corps of Engineers  
201 North 3rd Avenue  
Walla Walla, Washington 99362-1876

Dear Mr. Mettler:

**Re: Environmental Assessment (EA) and Draft Finding of No Significant Impact  
(FONSI) for the Ice Harbor Dam Spillway Deflectors Project**

The Washington Department of Fish and Wildlife (WDFW) is supportive of the proposed project as a reasonable effort to provide some relief from elevated total dissolved gas levels in the Ice Harbor Dam tailrace area and downstream. WDFW recognizes that the Corps is attempting to balance the expedited completion of this project against in-season fish passage operations. Your proposed date of August 1 for in-water construction which resulted in elimination of the August spill for juvenile migrant passage is unacceptable.

The EA is deficient and somewhat misleading at section 4a in that you fail to document that you expect a measurable additional mortality to occur for fall chinook juveniles as a direct result of the elimination of the August spill program. Your Appendix A should be cited at 4a as well as 4c and the specific mortality values reported.

In addition, WDFW believes that your analysis presented in Appendix A (Endangered Species Act Coordination Letter to National Marine Fisheries Service) underestimates the potential additional mortality for fall chinook. The underestimation is due to the assumption of exceptionally high flow for August. The BiOp flows have not been achieved in the recent past. The 1996 water temperatures to-date are far below average and have resulted in delayed development of fall chinook fry. This will likely result in migration timing as late or later than 1995.

The EA also fails to document that the proposed construction period far exceeds the established in-water work window of December through February. There is no rationale presented for the decision to recommend work outside this established period.

Lonnie E. Mettler  
May 20, 1996  
Page 2

5 WDFW also noted in your consultation letter to National Marine Fisheries Service that you did not include WDFW or any other Columbia River Basin salmon managers in the potential need for additional coordination should forced spill require modification of the construction program. We are hopeful that this was not an intentional omission and that you intend to include all Columbia River Basin salmon managers in further coordination on this project.

6 Your FONSI is also deficient in that there is not even a mention of your recommendation to delete the August spill program. We believe that this project does not qualify for a FONSI if in-water construction is started prior to September 1.

If you have questions regarding this response, please contact Mr. Rod Woodin at 360-586-4345.

Sincerely,

*Rodney M. Woodin*

Rodney M. Woodin  
Columbia River Policy Unit

cc: Bill Hevlin, NMFS  
Tom Cooney, WDFW  
Jim Nielsen, WDFW

Response to Washington Department of Fish and Wildlife letter dated May 20, 1996

Comment 1 - The Corps no longer plans to begin construction of the deflectors in August. Following a conference call with System Configuration Team (SCT) on May 15, 1996, the Corps agreed to delay start of construction until September 1. Therefore the August spill for juvenile passage will not be affected by construction of this project.

Comment 2 - When actual numbers of juvenile subyearling fish are applied to the most recently used parameter estimates in Analytical Coordination Group (ANCOOR) and National Marine Fisheries Service (NMFS) coordination, the worst case scenario for target flow ranges consistent with the 1995-98 Federal Columbia River Power System Biological Opinion (BiOp) (i.e., turbine mortality of 15%, 33% fish guidance efficiency (FGE), spill of 50-70% with no model accounting for dissolved gas supersaturation effects at higher summer water temperatures) estimated an absolute 1.05% mortality difference between the BiOp spill operation and the closed spillway operation for the month of August. These are for the 32% of subyearling juveniles indexed by the Fish Passage Center entering Lower Monumental during the later migration observed in 1995. The remainder of the analysis using either the lower turbine mortality estimate of 8% and/or higher FGE of 50% results in absolute mortality difference estimates of 0.8-78%. The Appendix should be cited in the environmental assessment (EA) text where appropriate. The intent of attaching the analysis as an Appendix is to incite the technical audience to review and understand the analysis, as well as control for misinterpretation between the technical analysis and the more generalized public audience targeted in the EA documentation process.

Comment 3 - No specific flow was assumed in the analysis. The analysis correctly accounted for actual operational scenarios requested under BiOp coordination. Scenarios such as spilling the 25 thousand cubic feet per second (Kcfs) spill cap with 30 Kcfs in the river are unrealistic, in that such an operation cannot physically occur. If any turbine unit is scheduled to operate, it requires 11 Kcfs at a minimum. Thus fish passage efficiency (FPE) has to be adjusted accordingly. The BiOp flow target is not considered to be that "exceptionally high" compared to historical natural runoff back-projections. It is not ecologically prudent to discount annual variability in summer flows by anthropomorphically averaging the historical data to derive a single target flow. It is highly probable with reasonable confidence that 1996 should provide flows more similar to 1995 (August average = 38.2 Kcfs, range of 33.1 - 49.5 Kcfs) than 1993 (August average = 33.9, range of 15.3 - 52.0 Kcfs) or 1994 (August average = 12.7 Kcfs, range of 10.9 - 17.3 Kcfs). To date, the high spring flows for 1996 have reduced the need for Dworshak augmentation. If the Technical Management Team (TMT) manages the available storage in Dworshak for subyearling benefits, there is good probability that the 55 Kcfs flow target of the BiOp can be achieved. It is fully the intent of the Corps to try to be consistent with the BiOp and achieve TMT requested and coordinated in-river flows, as per BiOp direction. The analysis in Appendix A (page 8) acknowledges the possibility of later migration timing based upon 1995 juvenile subyearling passage and arrival numbers, hence use of the 32% juvenile subyearlings remaining to pass Lower Monumental. It is also evident that the peak outmigration remained to occur during July for either the low flow year of 1994 and the higher flow year of 1995.

Comment 4 - The proposed in-water work window does extend beyond the established December-February work window. This work window has been coordinated with the Fish Facility Design Work Group and SCT and neither group has expressed concerns or objections to performing the work as long as in-water construction does not start before September 1. The construction of the spillway deflectors would take place on the downstream face of the dam. Few juvenile salmon are expected to be in the immediate work area between September and March. Generally the juveniles are not outmigrating during this time. Any spill during this time period would be in accordance with the 1995 Bi-Op and would be for high flows, not juvenile fish passage. Adults would be expected to use the fish ladders and would not necessarily be found holding in the construction area. The construction sequence would be to build the center deflectors first and work toward the outer spillways. The outer deflectors would probably not be constructed until after December, which would be within the established in-water work window. Construction would not impact salmon habitat.

Comment 5 - The coordination letter to National Marine Fisheries Service (NMFS) was prepared to fulfill Endangered Species Act (ESA) requirements. Under ESA, the Corps is required to coordinate/consult with the appropriate Federal agency for actions that may affect listed species. Since salmon are involved in this project, the appropriate agency is NMFS. The ESA does not require the Corps to consult with non-federal agencies. The Corps has coordinated this project with agencies and tribes through the FFDWG and the EA review process and will continue to do so, but under ESA, the Corps is required only to consult with NMFS.

Comment 6 - Please note that the Finding of No Significant Impact (FONSI) circulated with the EA was a draft FONSI and was prepared prior to the conference call in which the Corps agreed to push back the construction date to September. The draft FONSI did not mention the deletion of the August spill program because the deletion had not been raised as a major issue. At the time the draft FONSI was prepared NMFS had not expressed their concern about deleting August spill, data indicated that very few juvenile fall chinook would be migrating at that time, and the juvenile bypass facility was expected to be able to bypass most of the juveniles that might be migrating at that time.



DEPARTMENT OF THE ARMY  
WALLA WALLA DISTRICT, CORPS OF ENGINEERS  
201 NORTH THIRD AVENUE  
WALLA WALLA, WASHINGTON 99362-1876

Reply To  
Attention Of:

June 11, 1996

Planning Division

Jacqueline Wyland, Division Chief  
National Marine Fisheries Service  
Environmental and Technical Services Division  
525 N.E. Oregon Street, Suite 500  
Portland, Oregon 97232

Dear Ms. Wyland:

This letter responds to your May 24, 1996, coordination letter commenting on our proposed construction of flow deflectors at Ice Harbor Dam. Pursuant to the Reasonable and Prudent Alternative Intermediate Term Action No. 18 of the March 2, 1995, Biological Opinion on Operation of the Federal Columbia River Power System (BiOp), we recognize the BiOp requests spillway modifications for gas abatement at Ice Harbor Dam be completed "as soon as possible." Our interpretation of this request was to advance flow deflector design and construction to permit completion prior to the 1997 spring/summer chinook salmon outmigration.

Based upon coordination input from National Marine Fisheries Service (NMFS) staff, we changed the in-water activity start date from August 1, 1996 to September 1, 1996, in our Invitation For Bid/Solicitation For Construction (IFB/SFC) to construct deflectors in 8 of the 10 spillbays at Ice Harbor Dam. The proposed closure of the spillway will occur from September 1, 1996 through March 15, 1997. The IFB/SFC with the revised date went out for bid on May 17, 1996. An Amendment to this IFB/SFC went out for bid May 31, 1996, with the following additions:

a. A requirement that the contractor construct pier nose extensions prior to any activity related to deflector construction. The contractor retains the option to develop and select the dewatering and forming scheme. Our requirement allows for the contractor to develop a single-bay dewatering scheme that should reduce the risk of additional harm to juvenile migrants in the event that an hydrologic event would force spill during construction.

b. A request that the contractor work 7 days per week and 24 hours per day in an attempt to increase the probability of completing eight deflectors prior to the 1997 juvenile outmigration.

c. Deflector construction in spillbays two and nine are optional bid items determined by us. We have the right to exercise its option for construction in these bays based upon monitored contractor progress and hydrologic projections for flow and operating conditions.

d. Completion of deflectors in bays four, five, six, and seven by December 15, 1996. Completion of deflectors in bays three and eight by January 20, 1997. Completion of deflectors in bays two and nine by March 1, 1997, if we choose to exercise its option. The contractor then would have about two weeks of clean-up and demobilization to meet the scheduled completion date of March 15, 1997.

e. Additional language where we suggest the contractor should consider using more than one bulkhead system and drilling platform in an attempt to increase the probability of completing the proposed construction of eight deflectors by the scheduled completion date of March 15, 1997.

National Marine Fisheries Service should be aware that the revised IFB/SFC and its Amendment reflect that there is no guarantee on the part of our selected contractor to complete eight deflectors by March 15, 1997, although we will actively pursue an aggressive contractor to achieve a fully completed project by the original target date. We reiterate our biologically-related concerns about interim or long-term spill operations with a spillway configuration of less than eight deflectors versus the full eight deflector configuration. The concerns are based on the following considerations derived from physical model studies and field testing for total dissolved gas (TDG) supersaturation:

a. Operation of nondeflector bays adjacent to deflector bays have high influence on the TDG production dynamics and hydraulic conditions in the tailrace. Preliminary results from the Ice Harbor and John Day Dam general models for partial spillway installation of deflectors are discouraging for the development of suitable hydraulic conditions in the tailrace. Consistent with field testing data collected by the Waterways Experiment Station (WES), the creation of strongly unstable submerged lateral flow across the channel was observed in the hydraulic models. Submerged lateral flows transport aerated water that is supersaturated with gas due to plunging through nondeflected bays. We expect no measurable change in gassing or

degassing dynamics of this volume of water would occur with spill operations through a spillway with less than eight deflectors. If less than eight deflectors can be constructed in the September-March work window, the Technical Management Team or any other regional management body could not expect an interim spill cap during 1997 that would be greater than the 25 Kcfs that is presently used to control tailrace TDG to the 120 percent concentration allowed by the State's temporary water quality waivers.

b. Development of a suitable adult spill passage pattern will be required for Ice Harbor in the event fewer than eight deflectors are installed. The Ice Harbor 1:55 scale physical model demonstrated that adult ladder attraction conditions would be worse with six deflectors resulting in difficulty in developing a suitable interim pattern due to a relatively large amount of atmospheric air introduced to be plunged to hydrostatic pressure with depth. The chosen pattern would be implemented during the interim spill period of April 15 through September 1, 1997 (assuming construction of the remaining deflectors will begin September 1, 1997). Physical model studies performed during March and April of 1996, in preparation of the Feature Design Memorandum (FDM) No. 34, indicated additional deflectors may be installed in spill bays 1 and 10 without negatively impacting adult fish passage conditions. The installation of these deflectors may require training wall extensions between spillbays 9 and 10 and possibly between spillbays one and two. Preliminary model studies indicate a training wall extension between bays 9 and 10 may provide better than existing adult passage conditions downstream of the north spillway entrance either with or without a deflector in bay 10. Because of the accelerated schedule, it was not possible to address these items in the FDM. However, these modifications are currently being modeled and will be addressed in a supplemental letter to the FDM. If approved, construction of these additional modifications would require an extended in-water work window during September 1997 through March 1998. If the installation of all eight deflectors are not completed during the 1996-97 in water work window, the remaining deflectors would be installed during September, 1997 through March, 1998. This would likely impact the construction schedule for the proposed additional modifications, potentially resulting in lower annual smolt survival than expected and adult delay that could otherwise be avoided.

c. For future reference pertaining to analytical evaluations, single unit powerhouse minimum at Ice Harbor is 11 Kcfs per turbine under free-spin, no-load operation or 15-17 Kcfs under minimum load operation. This powerhouse operational constraint does not allow us to spill 25 Kcfs and operate a turbine unit when total river flow is less than 40 Kcfs. Adjusting the analysis in enclosure one of your letter, this powerhouse operational constraint lowers the WITH-SPILL SURVIVAL percentage estimates.

d. The biological evaluation in the FDM No. 34 (page 4-6) indicates no measurable net benefit to interim or long-term systemwide salmon survival with installation of flow deflectors at Ice Harbor Dam. The estimated increase in spill cap volume from 25 Kcfs to 45 Kcfs may increase the short-lived probability to exceed the 80 percent FPE target in the BiOp for a higher total river flow range while maintaining the 120 percent TDG. The incrementally small two to three percent projected survival due to this marginal increase in FPE could likely be canceled out by the moderate likelihood of a two to five percent increase in direct spill mortality (Johnsen and Dawley, 1974; Muir et al., 1995; Long et al., 1975). In addition to the direct spill mortality concern, possible delay of smolts may occur resulting in increased exposure to TDG supersaturation due to recirculation patterns created by the vertical rolling hydraulic conditions under higher spill discharges (i.e., the increase in reach travel time indicated in the NMFS PIT-tag analysis for 1995).

e. In the event of forced spill above the expected hydraulic capacity of the powerhouse (76 Kcfs with one turbine unit inoperable), all construction activity in the spillway must be terminated and abandoned until safe conditions resume. Turbine unit five is currently inoperable at Ice Harbor Dam and is scheduled to be inoperable through October 1996. A forced spill event would result in an unknown amount of delay in construction completion for any number of deflectors prior to the March 15, 1997, target date.

## Effects

### Juvenile

Biological Opinion on Operation of the Federal Columbia River Power System operations for juvenile passage beyond September 1, 1996, do not require voluntary spill at Ice Harbor Dam. Closure of the spillway from August 31, 1996, through March 15, 1997, would be consistent with fish passage operations guided by the BiOp.

### Adults

Adult Snake River fall chinook salmon are likely to be minimally affected by the proposed in-water construction activities, although spill generally detracts from adult passage conditions. There is potential for some minor near-field delay in ladder approach and entrance during low river flows, but the implementation is scheduled beginning with the center bays and working outward toward the ladder entrances to minimize potential effects of construction activity disturbance through noise or other emissions.


A consequence of partial deflector construction would be uncertainty associated with mechanical and TDG-related effects to adult migrants of all salmonid stocks while operating for an entire fish passage season relative to passage delay. Resultant hydraulic conditions would not be optimal according to more recent knowledge gained from 1993-1995 dam operations with voluntary spill and physical model studies. Voluntary spill patterns for adult and juvenile salmon passage during the 1997 outmigration would be highly weighted toward the use of deflector spillbays.

Summary

This letter is provided as a response to consultation with the NMFS for the proposed action of constructing flow deflectors in the centered spillbays at Ice Harbor Dam. We believe the closure of the Ice Harbor spillway from September 1, 1996 through March 15, 1996, would be consistent with BiOp RPA measure 4 that requires the spill operation for achieving the FPE target and not jeopardize the continued existence of listed Snake River salmon stocks or adversely modify their critical habitat beyond those assumed impacts and risks considered by NMFS in their BiOp for 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years.

If you have questions or require additional information, please contact me or Mr. Chris Pinney, Walla Walla District, Fishery Biologist, at 509-527-7284. Mr. Jim Athearn, at 503-326-2835, remains the North Pacific Division's ESA coordinator.

Sincerely,

  
James S. Weller  
Lieutenant Colonel, Corps of Engineers  
District Engineer

Copy Furnished:

Chris Toole  
National Marine Fisheries Service  
Endangered and Threatened Species Division  
Hydrology Branch  
525 N.E. Oregon, Suite 500  
Portland, Oregon 97232

Mark Schneider  
Chief, Operations Branch  
National Marine Fisheries Service  
525 N.E. Oregon, Suite 500  
Portland, Oregon 97232



Reply To  
Attention Of:

DEPARTMENT OF THE ARMY  
WALLA WALLA DISTRICT, CORPS OF ENGINEERS  
201 NORTH THIRD AVENUE  
WALLA WALLA, WASHINGTON 99362-1876

April 16, 1996

Planning Division

Dear Interested Party:

Enclosed for your review and comment are the Environmental Assessment (EA) and draft Finding of No Significant Impact (FONSI) for the proposed Ice Harbor Dam Spillway Deflectors project. These documents describe the impacts associated with installing spillway deflectors on Ice Harbor Dam on the lower Snake River near Pasco, Washington.

We invite interested parties to provide comments on the proposed project. Please provide your comments to:

Department of the Army  
Walla Walla District, Corps of Engineers  
ATTN: Chief, Environmental Resources Branch  
201 N. 3rd Ave.  
Walla Walla, WA 99362-1876

Comments should be postmarked no later than May 16, 1996 to ensure consideration.

Should you need additional information or have any questions, please contact Ms. Sandy Simmons at 509-527-7265.

Sincerely,

Lonnie E. Mettler  
Acting Chief, Environmental Resources Branch

Enclosures

Copy Furnished:

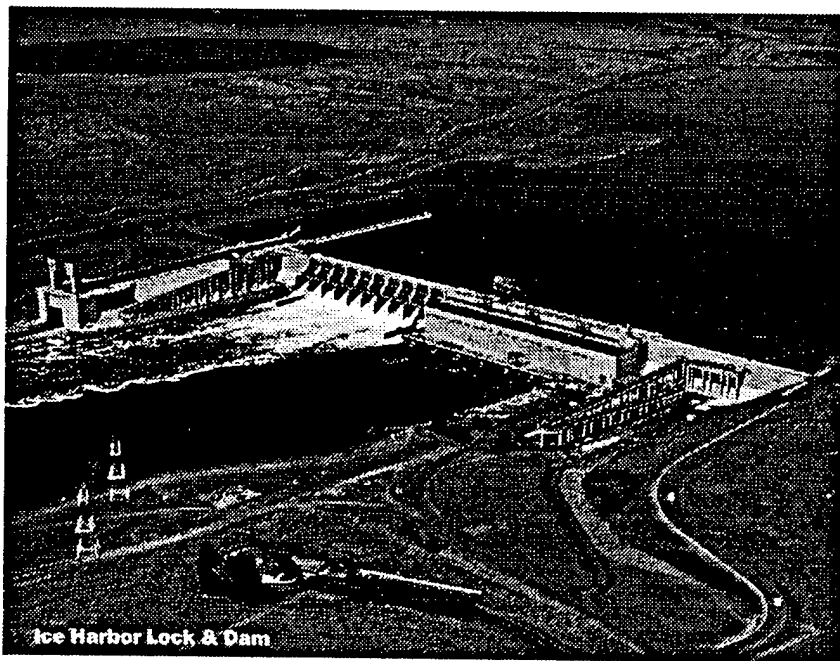
EN-DB-HY (Rick Emmert)  
✓ EN-DB-HY (Jim Cain)



U.S. Army Corps  
of Engineers  
Walla Walla District

# ENVIRONMENTAL ASSESSMENT ICE HARBOR DAM SPILLWAY DEFLECTORS

FRANKLIN AND WALLA WALLA COUNTIES, WASHINGTON



Prepared by  
Walla Walla District  
Corps of Engineers

April 1996

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## APPENDICES

- A - Endangered Species Act Coordination Letter to National Marine Fisheries Service

## 1. INTRODUCTION.

This environmental assessment considers effects of modifying the spillway of Ice Harbor Dam, which is located at River Mile 9.5 on the lower Snake River in southeastern Washington (Figure 1). The purpose of the modification is to reduce the amount of dissolved gas produced as river flows are passed through the dam spillway. As required by the National Environmental Policy Act (NEPA) of 1969 and subsequent implementing regulations promulgated by the Council on Environmental Quality, this assessment is prepared to determine whether the action proposed by the Corps of Engineers (Corps) constitutes a "...major Federal action significantly affecting the quality of the human environment..." and whether an environmental impact statement is required.

## 2. PROJECT PURPOSE AND NEED.

Salmon runs in the Snake River have declined rapidly in recent years, leading to the listing of these runs as threatened or endangered species under the Endangered Species Act (ESA). In response to this decline, the National Marine Fisheries Service (NMFS), the Northwest Power Planning Council (NPPC), and other regional agencies and groups requested the Corps to spill water at the eight federal dams on the Lower Snake and Columbia Rivers, including Ice Harbor Dam, to try to improve juvenile salmonid fish passage in the Snake and Columbia Rivers. At the request of the NPPC, the Corps started spilling water in 1989 throughout the river system in an attempt to pass outmigrating juvenile salmon through dams that did not have juvenile bypass systems. In 1994, the Corps started spilling water at NMFS' request to try to increase passage of outmigrating juvenile salmon through the spillways in addition to routing them through the bypass systems. However, spilling causes the river flows to plunge into the water below the dams, trapping air in the water and resulting in high concentrations of total dissolved gas (TDG). High TDG can injure or kill juvenile and adult salmon, as well as resident fish and other aquatic organisms.

The Corps has made earlier efforts to reduce TDG concentrations. In the 1970's, spillway deflectors (also known as fliplips) were installed on three of the Lower Snake River dams (Lower Granite, Little Goose, and Lower Monumental) and two of the Columbia River dams (McNary and Bonneville) as a temporary measure to reduce TDG when high flows exceeded powerhouse capacity and water had to be released through the spillway, usually during spring runoff. The deflectors were installed on the lower part of the spillway to keep the water from plunging deep into the stilling basin below the dams. Deflectors were not installed on Ice Harbor Dam because of concerns that deflectors would cause poor hydraulic conditions below the dam that would delay or block adult salmon passage. It was also believed that TDG would already be reduced by the upstream dams because of their greater capacity to store water rather than spilling it and, once the additional turbine units were installed, their greater capacity to run water through the powerhouse rather than spilling water involuntarily. However, the need for TDG abatement surfaced again with the listing of Snake River salmon under ESA. In their March 1995 Biological Opinion on Operation of the Federal Columbia River Power System, under Reasonable and Prudent Measures Intermediate Term Action No. 18, NMFS requested that spillway modifications for gas abatement at Ice Harbor Dam be completed as soon as possible, contingent on the results of TDG abatement evaluations in 1995 and 1996.

### 3. ALTERNATIVE ACTIONS.

The Corps investigated several actions it could take to reduce TDG concentrations at Ice Harbor Dam. These ranged from changing operation at the dam to structural changes. Because of the immediate regional concern about high TDG, the primary selection criteria was the action had to be something that could be implemented quickly. Most of the alternative actions are still being investigated as part of the on-going gas abatement studies and may take between 4 and 10 years to implement. The Corps identified only one alternative, spillway deflectors, that would provide meaningful reduction in TDG and could be implemented in time for the 1997 outmigration.

This section describes alternatives considered by the Corps to provide some reduction in TDG concentrations until a better solution is identified through on-going gas abatement studies. The alternatives include several that may be considered for implementation in the future, either by themselves or in various combinations.

#### a. Proposed Action. (Spillway Deflectors)

The preferred alternative is to construct spillway deflectors on up to ten spillbays of Ice Harbor Dam and to extend one or both of the training walls between spillbays 1 and 2 and between 9 and 10 (Figure 2). The deflectors would be shaped somewhat like a shelf with a vertical downstream face and a slightly curved top (Figure 3) to force spilled water to flow horizontally (skimming flow) rather than plunging to the bottom of the stilling basin. Each deflector would extend across the entire 50-foot width of the spillbay. The top of the center eight deflectors would be at an elevation about 34 feet higher than the bottom of the stilling basin and about 4 to 10 feet below the normal tailwater elevation. The elevation of the outer two deflectors has yet to be determined, but will be selected to provide optimum conditions for adult fish entering the adjacent ladders. The Corps, using data from pre- and post-deflector data from Lower Monumental Dam, has estimated that installing deflectors of this design at Ice Harbor Dam could possibly reduce dissolved gas supersaturation by up to 5- to 10-percent for spills flows up to 60,000 cubic feet per second (cfs).

The Corps would construct the deflector project in two stages. During the first construction period extending from August 1, 1996 to March 15, 1997, the Corps would install deflectors in the center eight spillbays. During the second construction period anticipated to extend from August 1, 1997 to March 15, 1998, the Corps would install deflectors on the two outside spillbays and extend the training wall(s).

The Corps has identified several ways the spillway deflectors could be constructed although the actual method to be used will be up to the contractor. One of the quickest ways to construct the deflectors would be to use floating bulkheads to block water from the construction area. A bulkhead would be floated to the spillbay, positioned at the location of the downstream face of the deflector, and filled with water to cause the bulkhead to sink. The bulkhead could also function as a form for placing the concrete deflector. Concrete would be placed underwater, in the dry, or

a combination of both. Any water displaced by the concrete would be pumped into a holding tank on a barge to allow sediment to settle out. Should the need arise to spill water during construction, the bulkhead could quickly be removed in less than a day.

Another possible construction method would be to use a different floating bulkhead (existing navigation lock bulkhead) that, when used as a pair, would span three spillbays simultaneously. These bulkheads would be positioned slightly downstream of the downstream face of the deflectors. The contractor would need to fabricate a steel "table" for the bulkheads to rest on, plus training wall seals and braces to keep the bulkheads in place. Divers would have to drill holes in the spillbay to anchor these steel support structures. The work area behind the bulkheads would be dewatered and a separate form would be constructed for pouring the concrete deflectors. Should the Corps need to spill water during construction, the bulkheads could quickly be removed, but the steel table and bracing would have to remain and may be damaged or torn from the dam by the force of the water.

Yet another possible method would be for the contractor to fabricate a lightweight underwater form and place the concrete behind the form. Any water displaced by the concrete would be pumped into a holding tank on a barge to allow sediment to settle out.

Under any of the construction methods, the contractor would have to drill holes into the spillway using a barge-mounted drill and divers. Some of these holes would be for placing anchors for the concrete. The anchors would then be grouted. Some of the holes would be for chipping or blasting concrete from the spillbay for construction of the upper curved portion of the deflector.

There is a possibility the Corps would need to spill water during the construction period, although the Corps would attempt not to use spillbays in which construction was taking place. Should the Corps need to spill water over an unfinished deflector, the force of the spilled water hitting the concrete would likely cause the concrete to dissolve or crumble and be carried into the stilling basin. The dissolved concrete would quickly dissipate downriver with only a negligible effect on water quality.

As part of the 1997-98 construction stage, the Corps would extend one or both of the training walls along the outer spillbays. The Corps does not have definitive information at this time to determine how many walls will be extended and what configuration they would have. The preferred option at this time is to extend the wall between spillbays 9 and 10 to improve adult fish attraction flows and hydraulic conditions at the north fish ladder entrance. The Corps will perform additional physical hydraulic modeling to further refine this decision.

The construction method for the training wall extension(s) would be similar to that used for the spillway deflector construction. The contractor would drill holes into the stilling basin floor to anchor the wall extension. Bulkheads would probably be used to block off the construction area while concrete for the wall extension was being poured. The bulkheads might double as forms for the wall. The concrete might be placed underwater or the area might be dewatered before the concrete is placed.

There is a possibility that the entrances to the adult fish ladders may be extended to improve conditions at the entrances. This is because operation of the deflectors may change flows downstream of the dam in such a manner that adult salmon may have difficulty locating the ladder entrances. The Corps will continue to evaluate this possible problem, through physical model studies and post-construction biological evaluations, to determine what actions need to be taken.

The Corps plans to complete construction of the center eight spillway deflectors in time for the spring 1997 outmigration. At that time the Corps would operate the spillway in the normal manner for spring runoff flows or would voluntarily spill water as recommended by the NMFS for fish passage. The Corps would observe conditions during the 1997 operation and use that information to finalize design for the remaining two spillway deflectors and the training wall extension(s).

b. No Action.

Under this alternative, the Corps would not construct spillway deflectors nor extend the training wall(s). The Corps would continue to operate the spillway for passing excess flows that could not be passed through the powerhouse. The Corps would continue to spill water during the spring outmigration period as requested by NMFS. The dam would continue to produce high TDG during spill. The Corps would continue to study and design more viable TDG abating concepts for future construction and operation.

c. Alternatives Removed from Further Discussion.

1) Modified Stilling Basin

A different structural alternative to reduce dissolved gas would be to modify the configuration of the stilling basin (Figure 2). Under this alternative the Corps would modify the stilling basin in one of two ways. The first would be to raise the elevation of the stilling basin floor about 18 feet to reduce the depth of the water in the tailrace below the dam. This would prevent the water coming through the spillway from plunging as deep and would reduce TDG. However, this would not dissipate the water energy in a controlled manner and could result in erosion and redeposition of gravel and rock in the navigation channel and the river bed.

A second way to modify the stilling basin would be to construct a downward stepped stilling basin. The Corps would construct a raised stilling basin (primary basin) as described above, but would excavate a deeper stilling basin (secondary basin) immediately downstream of the primary basin. The primary basin would reduce TDG during low flows while the secondary basin would help dissipate energy. However, during high flows, the stepped basin may result in unacceptably high TDG concentrations.

The Corps has insufficient data to determine the effectiveness of these designs at this time and has concerns and questions about the effects on fish passage conditions, stream bed erosion, and the navigation lock. The Corps is not in a position to implement this alternative in 1996 for 1997

operation, therefore this alternative has been eliminated from consideration at this time. The Corps will continue to study raised stilling basin concepts through the Corps' Dissolved Gas Abatement Study.

## 2) Raised Tailrace

Under this alternative the Corps would raise the elevation of the tailrace by placing rockfill and large quarry stone riprap on the riverbed starting at the end sill and extending 500 feet or more downstream of the stilling basin. The fill material would slope upward from the stilling basin to dissipate energy, then slope downstream.

As is the case with the stilling basin modifications, the Corps has insufficient data to determine the effectiveness of this design at this time and has concerns and questions about the effects on fish passage conditions, stream bed erosion, and the navigation lock. The Corps is not in a position to implement this alternative in 1996 for 1997 operation, therefore this alternative has been eliminated from consideration at this time. The Corps will continue to study a raised tailrace concept through the Corps' Dissolved Gas Abatement Study.

## 3) Operational Changes

Under this alternative the Corps would change the pattern it uses to spill water through the spillway. In 1995, the Corps tested an alternate spill pattern designed to minimize TDG from Ice Harbor spill. The Corps detected lower TDG in the tailwater when operating with the alternate spill pattern. The alternate pattern was able to reduce TDG by 3-4% at high discharge levels (60,000-70,000 cfs). However, TDG still remained above 125% for all spill over 25,000 cfs. Changes in spill operation alone would not resolve the TDG problems resulting from spill at Ice Harbor. However, there is potential for minimizing or reducing TDG simply by altering the spill pattern.

The effect of the alternate spill pattern on adult fish passage is uncertain. As an interim operation to assist in the reduction of TDG, it may be beneficial to use the new pattern at night and use the standard pattern during the day when the adult fish are seeking passage. Further testing is needed to determine the impact on adult fish passage as well as the effectiveness of the alternate pattern at various spill discharges and forebay TDG concentrations.

Because this alternative would not provide adequate reduction of TDG at Ice Harbor, this alternative was eliminated from further discussion for implementation in 1996. This alternative may be implemented in the future depending on the results of further testing.

## 4) No Voluntary Spill

There are two options under this alternative. Under the first option the Corps would not voluntarily spill water at Ice Harbor for juvenile fish passage. This would eliminate high TDG associated with voluntary spill, but would not fulfill NMFS' request that the Corps spill for fish

passage. It would also not reduce TDG during involuntary spill and thus was removed from further consideration.

Under the second option, the Corps would install extended-length fish screens at Ice Harbor Dam to improve the ability of the dam to direct juvenile fish away from the turbines and into the juvenile bypass system of the dam. Since a major goal of the region is to keep juvenile fish away from the turbines, either through bypass or spill, the Corps might not need to spill for juvenile fish passage if the Corps improves the efficiency of the bypass system. However, this would not reduce TDG levels during involuntary spill and was eliminated from consideration at this time. The Corps may consider installing extended-length screens in the future.

#### 4. AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES.

##### a. Aquatic Environment.

Three species of salmon pass over Ice Harbor Dam: spring/summer chinook, fall chinook, and sockeye salmon. The two chinook species are listed as threatened species under ESA while the sockeye salmon is listed as endangered. Ice Harbor Dam is the first Snake River dam encountered by adult salmon migrating upstream to spawn and the last dam encountered by outmigrating juvenile salmon before they enter the Columbia River.

Construction of the spillway deflectors would have minimal impacts on aquatic resources in the vicinity of the dam. No important fish habitat would be disturbed by the construction. Fish and other organisms in the river would easily avoid the construction activities. Any fish trapped in the work area would be released back into the river. There is the possibility that high river flows during the construction period could force the Corps to spill water over the construction area on the spillway. Fish caught up in the spill may strike the exposed anchors and bulkhead support structures (if the bulkhead with "table" method is being used) and be injured. Since the Corps plans to start construction in August, the Corps would not be able to spill water for juvenile fall chinook passage during August. However, the juvenile bypass facilities at the dam would be operational during that period and the fall chinook would be able to pass the dam through those facilities.

Operation of the spillway deflectors is expected to decrease TDG when water is being spilled, which would improve in-water conditions for salmon as well as other aquatic organisms. Dissolved gas levels are of concern because gas supersaturation can lead to the development of gas bubble "disease" in fish and aquatic organisms. This condition can produce a variety of signs and physiological changes that are often fatal. Adult salmon are more susceptible to the effects of TDG supersaturation than juveniles due to their more developed organs. High gas saturation levels may also cause food organisms for juvenile salmon to involuntarily float away from salmon rearing and staging areas.

Spill at Ice Harbor Dam, both involuntary during high flows and voluntary for fish passage, causes TDG supersaturation that can exceed the established Washington water quality standard and Federal water quality criteria of 110 percent of barometric pressure. In recent years the

Corps has operated under temporary waivers for endangered species considerations that allow TDG exceeding that standard. Extremely high TDG has been recorded immediately below the dam during spills greater than 60,000 cfs. Research indicates that TDG concentrations above 120 percent can be lethal and lead to death or chronic physiological stress in juvenile salmon with enough exposure time. Adult salmon are negatively affected at TDG below 110 percent and TDG of 115 percent can be lethal. The Corps has estimated that installing deflectors at Ice Harbor Dam may reduce TDG by 5 to 10 percent at the current spill cap level of 25,000 cfs. If the deflectors are able to reduce TDG closer to between 110 and 115 percent, adult and juvenile salmon survival could be increased.

Ice Harbor Dam has two fish ladders to provide upstream passage for adult salmon migrating upstream to spawn. The entrance to the north ladder is adjacent to the north side of spillbay 10 while the south ladder entrance is adjacent to the south side of spillbay 1. Since adult salmon are attracted to strong flows, the Corps provides attraction water at the entrance of each ladder to help the adults find the ladders. Operation of the spillway deflectors may impact adult salmon passage conditions. The water moving over the deflectors may pull flows from the powerhouse over towards the stilling basin, creating a lateral flow across the downstream face of the dam. This lateral flow could produce turbulence that may confuse adult fish and discourage them from entering the fish ladders. However, model studies indicate operation of the deflectors would not create adult passage conditions worse than existing conditions. Extending the training wall between spillbays 9 and 10 may help reduce the turbulence and direct adults to the fish ladder.

The impact of the spillway deflectors on passage conditions for juvenile salmon going through the spillway is unknown. The stilling basin at Ice Harbor Dam was designed to dissipate energy generated by water flowing over the spillway, not to provide passage for juvenile salmon or other aquatic organisms. The configuration of the stilling basin and the placement of the concrete baffles were designed to dissipate kinetic energy from the water spilling through the spillway to reduce turbulence and shoreline erosion downstream of the dam. Juvenile fish passing through the spillway may be driven against the concrete baffles as the water loses energy. Passage conditions may improve with the installation of the deflectors. The deflectors should produce a skimming flow along the surface of the water. This skimming flow may be sufficient to carry the juvenile salmon across the top of the concrete baffles at the downstream edge of the stilling basin (Figure 3). However, the flow may still force the fish into the rolling water between the baffles and the end sill wall, battering the fish against the concrete.

b. Wildlife.

Wildlife use of the immediate area below Ice Harbor Dam is primarily by birds. Cliff swallows nest on the dam structure and may forage for insects over the tailrace. Numerous species of waterfowl rest and forage in the water below the dam. Ring-billed gulls perch on the dam structure and prey on fish that have passed through the turbines or the spillway.

Construction activities would not impact wildlife use at the dam. Construction activities would take place when birds are not nesting. Any birds in the area would easily be able to avoid the work activities.

Operation of the deflectors would not negatively impact wildlife use at the dam. Birds would generally avoid the areas of water turbulence. Gulls would still be attracted to the tailrace area during spill operations to feed on stunned juvenile salmon passing through the spillway.

c. Endangered Species.

As mentioned in section 4.a., three species of listed salmon pass over Ice Harbor Dam: spring/summer chinook, fall chinook, and sockeye salmon. The Corps has written a coordination letter to NMFS stating that the construction of the spillway deflectors is not likely to adversely affect these listed species. A copy of this letter is in Appendix A. The Corps proposes installing the spillway deflectors as per the Biological Opinion on Operation of the Federal Columbia River Power System prepared by NMFS in March 1995.

Federal agencies are required to consult with USFWS for actions they intend to implement that may jeopardize the existence of listed species. The Corps has identified two species, the wintering bald eagle and the migrating peregrine falcon, which may utilize the habitat in the project area. No impacts to individuals of these listed species are anticipated by the construction and operation of the spillway deflector project. The proposed work site is already disturbed and is a center of human activities. Any eagles or falcons in the vicinity of the project would be passing through and would easily avoid the construction site. The construction and operation of the spillway deflector project would not affect food sources for either of the species. Based primarily on the fact that wintering bald eagles and migrating peregrine falcons will not be present during the construction window (August - March) and that food sources or habitats of these two species would not be affected, the Corps has made a "No Effect" determination.

5. ENVIRONMENTAL REVIEW REQUIREMENTS.

The following paragraphs address the principal environmental review and consultation requirements applicable to Corps of Engineers civil works actions. Pertinent Federal statutes, executive orders, and executive memorandums are included.

a. Reservoir Salvage Act; National Historic Preservation Act; Executive Order 11593, Protection and Enhancement of the Cultural Environment.

The project constitutes a modification to an existing non-eligible structure. A finding of "no effect to cultural or historic properties" has been forwarded to the Washington State Historic Preservation Office.

b. Clean Air Act.

This EA has been provided to the Environmental Protection Agency in compliance with this Act.

c. Clean Water Act.

Placement of temporary bulkheads and construction of the spillway deflectors and training wall extension will be subject to the requirements of the Clean Water Act. Placement of temporary bulkheads is covered under nationwide permit number 33, Temporary Construction, Access and Dewatering. Construction of the deflectors and training wall extension is covered under nationwide permit number 25, Structural Discharge, as the concrete and grout for these structures will be placed in tightly sealed cells. Construction of the training wall extension(s) is subject to Section 10 requirements, but because the training wall extension(s) would be located in an area closed to boat traffic there would be no impacts on navigation. The contractor will be required to obtain a water quality standards modification from Washington Department of Ecology for the discharge of the pulverized concrete from the anchor drilling if the contractor chooses not to capture the cuttings for upland disposal. The contractor will be required to obtain a Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife (WDFW) prior to installing the deflectors and training wall extension(s).

d. Endangered Species Act of 1973, as Amended.

See Section 4.d. The Corps has determined that construction and operation of the proposed project would have "No Effect" on listed wildlife species. The Corps has also determined construction of the proposed project is not likely to adversely affect listed salmon stocks.

e. Wild and Scenic Rivers Act.

This segment of the Snake River is not included on the inventory of wild and scenic rivers.

f. Fish and Wildlife Coordination Act.

Under this act, federal agencies proposing water resource development projects are required to coordinate with the USFWS for evaluation of effects the project may have on fish and wildlife resources. The Corps has coordinated with the USFWS (telephone conversation on December 13, 1995, between Lonnie Mettler of the Corps and Dan Haley of USFWS) and discussed the deflector project. The Corps and USFWS agreed there would be no need for a Coordination Act Report or a Planning Aid Letter as long as there was no change in the alternatives as described in this EA.

g. National Environmental Policy Act (NEPA).

This EA was prepared as required by the Act. The NEPA process will be complete when either a Finding of No Significant Impact is signed or an Environmental Impact Statement is prepared.

h. Northwest Electric Power Planning and Conservation Act.

The proposed project is in compliance with this Act and the fish and wildlife program developed pursuant to the Act.

i. Executive Order 11988, Floodplain Management.

The proposed action would not adversely affect floodplain resources and would not contribute to future development in the floodplain.

j. Executive Order 11990, Protection of Wetlands.

The proposed action will not affect wetland areas.

k. CEO Memorandum, August 11, 1980, Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing NEPA.

No agricultural land will be affected.

6. CONSULTATION AND COORDINATION.

Development of this project has been coordinated with NMFS, Washington Department of Fish and Wildlife, and other agencies with representation in the Fish Facility Design Work Group.

Copies of this Environmental Assessment have been sent to:

U.S. Environmental Protection Agency  
Seattle, WA

Idaho Department of Environmental Quality  
Lewiston, ID

U.S. Fish and Wildlife Service  
Moses Lake and Vancouver, WA

Oregon Department of Fish and Wildlife  
Portland and Clackamas, OR

National Marine Fisheries Service  
Portland, OR

Oregon Department of Environmental  
Quality  
Pendleton, OR

Washington Department of Fish and Wildlife  
Olympia, Kennewick, Spokane, and Walla  
Walla, WA

Office of Archaeology and Historic  
Preservation  
Olympia, WA

Washington Department of Ecology  
Olympia and Spokane, WA

Columbia River Intertribal Fish Commission  
Portland, OR

Idaho Department of Fish and Game  
Lewiston, ID

Northwest Power Planning Council  
Portland, OR

Columbia Basin Fish and Wildlife Authority  
Portland, OR

Confederated Tribes of the Umatilla Indian  
Reservation  
Pendleton, OR

Nez Perce Tribe of Idaho  
Lapwai, ID

Walla Walla County Commissioners  
Walla Walla, WA

Franklin County Commissioners  
Pasco, WA

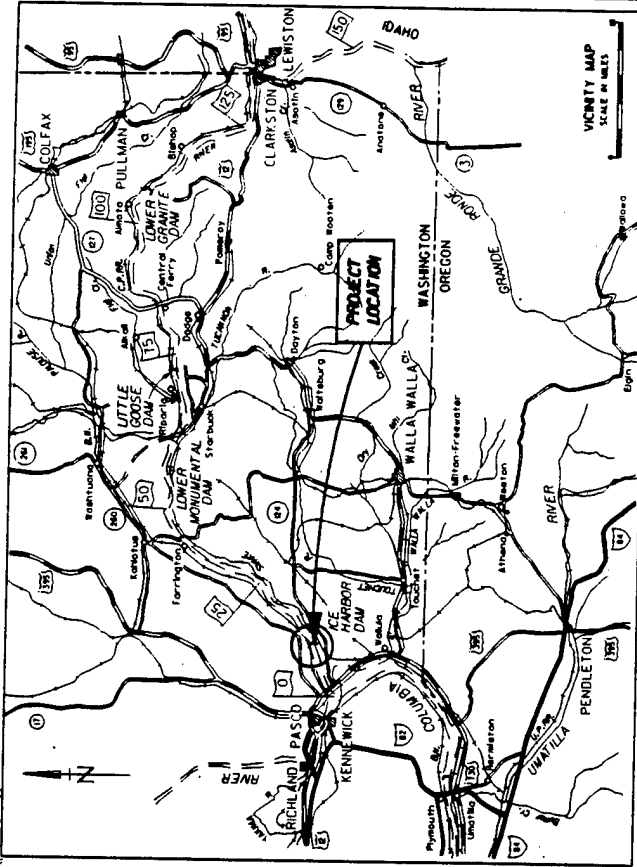
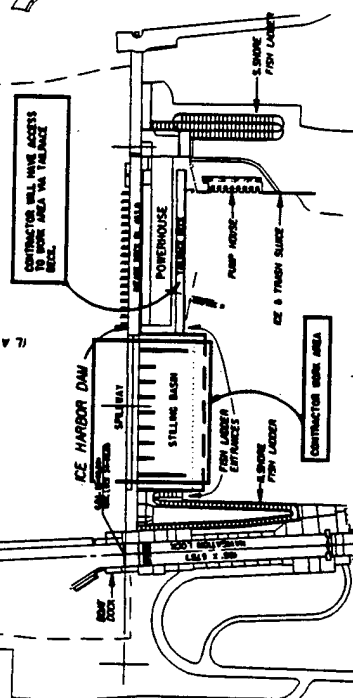
Tri-State Steelheaders  
Walla Walla, WA

Tri-City Herald  
Tri-Cities, WA

Walla Walla Union-Bulletin  
Walla Walla, WA



R I V E R  
L A K E S A C A W E N



U. S. ARMY ENGINEER DISTRICT WALLA WALLA, WASHINGTON	
ICE HARBOR LOCK & DAM SNAKE RIVER, OREGON, WASHINGTON & IDAHO	
SPILLWAY DEFLECTORS LOCATION MAP	
PROJECT NO.	1
DATE	15 SEP 50
BY	W. E. H.
CHECKED BY	W. E. H.
APPROVED BY	W. E. H.
SCALE	1" = 10 MILES

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NOTE:  
DAM WAS COMPILED FROM CONTRACT SHEETS  
AND LIFTED FROM AERIAL PHOTOS.  
AERIAL PHOTOS WERE USED TO CORRECT  
AERIAL PHOTOS AND ARE ONLY APPROX.

EXISTING  
FISHWAY

SPELLING DAM

EXISTING  
DAM

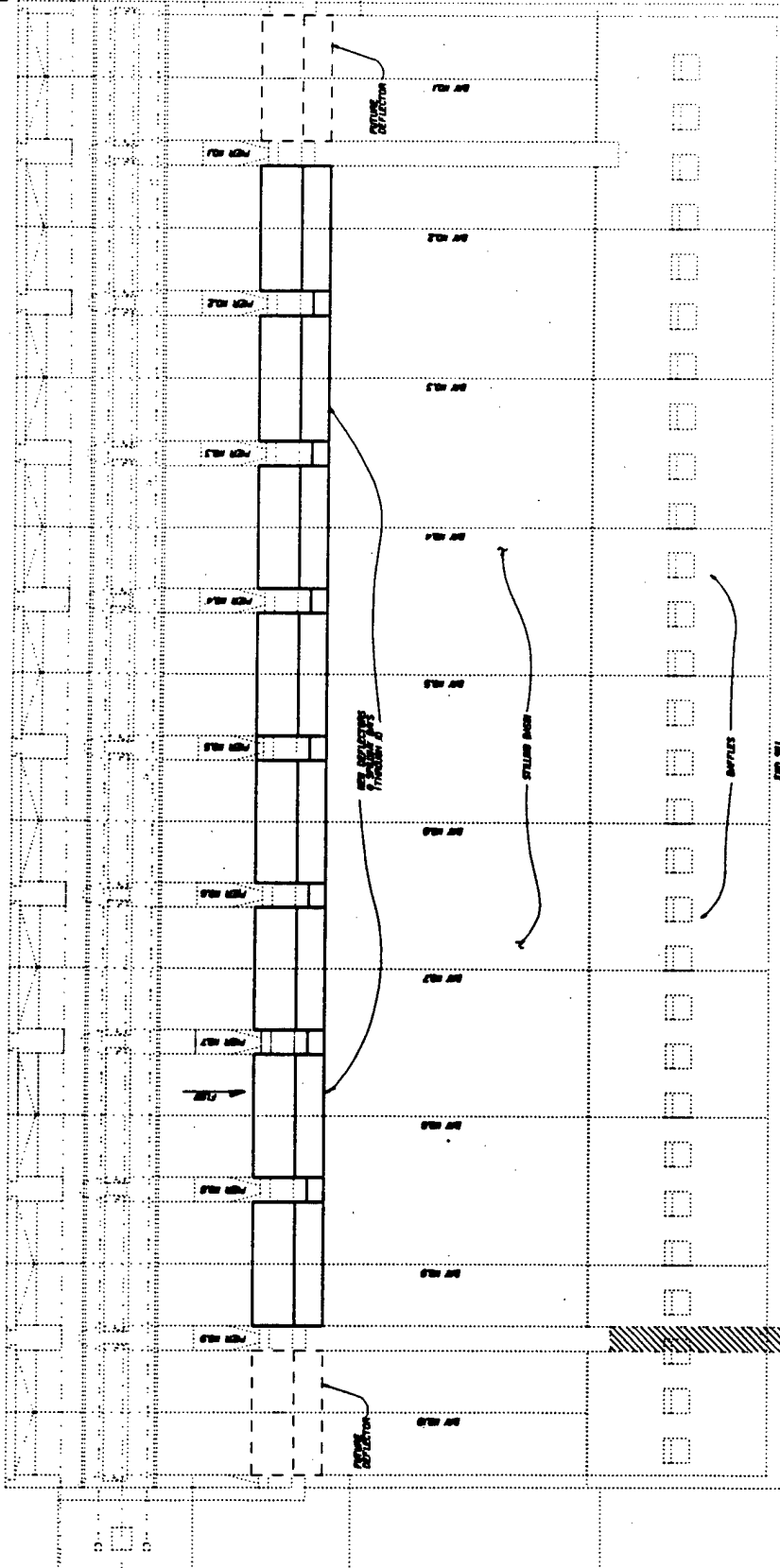
STA. 0+00

STA. 0+20

EXISTING  
DAM

EXISTING  
DAM

EXISTING  
DAM



PLAN

SCALE 1" = 20'

U. S. ARMY ENGINEER DISTRICT BALLA BALLA, WASHINGTON	
PROJECT ICE HARBOR LOCK & DAM SALE WITH DESIGN, INSPECTION & CONSTRUCTION	DATE 10/1/54
SPECIALTY SPILLWAY DEFLECTORS SPILLWAY & STILLING BASIN PLAN	
DESIGNED BY H. J. HARRIS	CHECKED BY H. J. HARRIS
SCALE 1" = 20'	DATE 10/1/54
FIG-1-0-1/279	

LEGEND  
 --- EXISTING STRUCTURE  
 --- NEW STRUCTURE

COMPUTER  
AND  
DRAWING  
BY  
H. J. HARRIS  
10/1/54

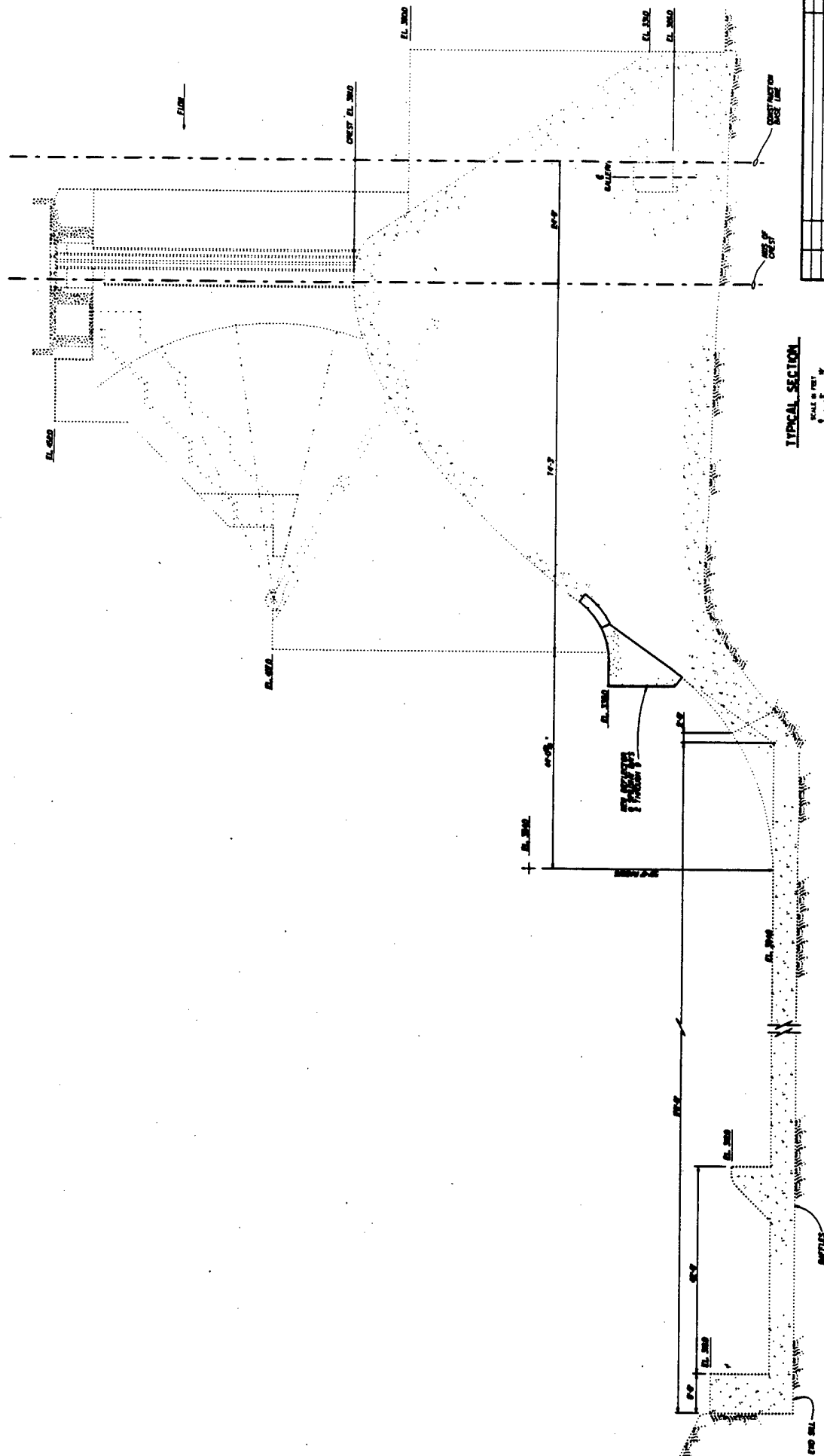
VALUE ENGINEERING PAYS

INDICATES REFERENCE FILE DISPLAYED

LEVELS ON FOR CONTRACT DOWNS

SCALE

FIGURE 2



TYPICAL SECTION

SCALE 1/4\"/&gt;

LEGEND  
 ———— EXISTING STRUCTURE  
 - - - - - NEW STRUCTURE



U. S. ARMY ENGINEER DISTRICT  
 BALLA BALLA, BANGKOK

ICE HARBOR LOCK & DAM  
 SAME WITH DESIGN REVISIONS & DAM

SPILLWAY DEFLECTORS  
 SPILLWAY & STILLING BASIN  
 SECTION

SCALE 1/4\"/>

FIGURE 3  
 MG-1-0-1/280

VALUE ENGINEERING PAYS

\* INDICATES REFERENCE FILE DISPLAYED REFERENCE FILE ATTACHED

**Appendix A**

**Endangered Species Act Coordination Letter to  
National Marine Fisheries Service**



DEPARTMENT OF THE ARMY  
WALLA WALLA DISTRICT, CORPS OF ENGINEERS  
201 NORTH THIRD AVENUE  
WALLA WALLA, WASHINGTON 99362-1876

April 16, 1996

Reply To  
Attention Of:

Planning Division

Jacqueline Wyland  
Division Chief  
National Marine Fisheries Service  
Environmental and Technical Services Division  
525 N.E. Oregon Street, Suite 500  
Portland, Oregon 97232

Dear Ms. Wyland:

Pursuant to the Reasonable and Prudent Alternative Intermediate Term Action No. 18 of the March 2, 1995, Biological Opinion on Operation of the Federal Columbia River Power System (BiOp), we are completing a design memorandum and plans and specifications to construct eight spillway flow deflectors at Ice Harbor Dam. The BiOp requests that spillway modifications for gas abatement at Ice Harbor dam be completed "as soon as possible." The Corps interpretation of this request was to advance flow deflector design and installation targeted at operation prior to the 1997 spring/summer chinook salmon outmigration beginning April 15, 1997. The deflectors, often referred to as "fliplips", are designed to direct spillway flow in a skimming manner which acts to reduce the production of total dissolved gas supersaturation (TDGS) resulting from high spill Kcfs.

This letter is provided as coordination for your review and comment. The Walla District, U.S. Army Corps of Engineers, plans to construct deflectors in eight of the ten spillbays at Ice Harbor Dam. This proposed action will likely require the entire ten (10) bays of the spillway to be closed for seven and one-half (7.5) months. The proposed closure of the spillway will occur from August 1, 1996, through March 15, 1997. The Walla Walla District has included a clause in the construction contract that spill during the month of August 1996 is highly desired and will be encouraged by the Corps to be consistent with the BiOp Reasonable and Prudent Alternative operation for summer migrants. The ability to schedule and provide spill especially for juvenile salmon during nighttime hours throughout August 1996, unless absolutely necessary as per the contractor's anticipated schedule, will be tightly coordinated between the Corps, National Marine Fisheries Service (NMFS), and the contractor.

Snake River salmon stocks listed under the ESA are not likely to be adversely affected by the proposed activities beginning in August, 1996.

During final preparation of the Feature Design Memorandum (FDM) No. 33, physical model studies identified additional changes to the Ice Harbor Dam spillway which could provide enhanced dissolved gas control and adult fish passage hydraulic conditions following the 1997 outmigration season. These changes include possible additional deflector installation on bays 1 and 10 and/or extensions of the north and south training walls to the end sill of the stilling basin. It was not possible to fully address these items in the FDM because of accelerated schedules.

The new collection channel and dewatering structure for the juvenile bypass system at Ice Harbor Dam became operational on April 1, 1996. Operation of the new juvenile bypass facility was included in the formal consultation of the Federal Columbia River Power System for 1994 through 1998 (March 1994) and will be operated to pass smolts during the August through October 1996 closure of the spillway. The NMFS concluded that the proposed actions (for juvenile bypass facility operation) would not jeopardize the continued existence of listed Snake River salmon stocks or adversely modify their critical habitat. However, no post-construction evaluation has been conducted to date. Assuming that no unanticipated malfunctions in the new juvenile bypass facility during the post-construction evaluation during Spring 1996, operation of the facility for summer fish under full bypass mode should not affect summer and fall chinook condition greater than the 2 percent bypass mortality rate observed at upriver collection facilities. The spring chinook evaluations will end before June 1, 1996, with no sampling anticipated for summer outmigrants during 1996.

#### Proposed Action

We plan to construct 8 deflectors at elevation 338 feet within spillbays 2 through 9 at Ice Harbor Dam. In-water construction may begin as early as August 1, 1996, and may continue through March 15, 1997 (Enclosure 1). Walla Walla District engineers have estimated the construction of a full set of 8 deflectors cannot be completed during the traditional work window of December through February. The decision to install 8 deflectors was dependent on physical model results indicating suitable adult fishway attraction hydraulic conditions. Model demonstrations were coordinated during a March 1996 trip to Waterways Experiment Station (WES) by Gary Fredricks and Steve Rainey of NMFS, Joel Hunt of the University of Idaho,

and a group of Corps hydraulic engineers and Operations Division biologists. The outside spillbays (nos. 1 and 10) will remain without deflectors during the 1997-98 juvenile salmon passage season. Physical model studies performed in March 1996 indicated that deflectors possibly should be installed in the outside spillbays 1 and 10 to reduce the amount of atmospheric air available to be plunged to hydrostatic pressures at depth. The installation of deflectors in bays 1 and 10 will not necessarily provide better adult attraction. However, the model demonstrated that attraction conditions would likely be no worse than with the 8 bay pattern. In addition, north and south training wall extensions will likely be required in the future to better entrain and direct the flow from these bays downriver. The training wall extensions should provide improved adult attraction conditions.

#### Pre-Drilling for Anchor Bolt and Rebar

Beginning as early as possible in August 1996, a barge-mounted drilling rig will access each spillbay from the tailrace for drilling anchor bolt and rebar tie holes constituting the 15-degree radius transition curve from each spillbay face to each 12.5 foot long deflector.

The pre-drilling for anchor bolt placement will be performed prior to floating bulkhead installation and partial spillway dewatering. Based upon an assumed schedule needed by the contractor to complete the proposed project, it is anticipated that no spill would be allowed during daytime hours in order to maintain a stable platform. This would reduce spill for passage of juvenile salmonids during the daylight hours when individuals are expected to be in the immediate forebay area waiting to pass the dam. The juvenile bypass system will be operated during this no-spill period. The no-spill operation may possibly cause some delay to adult attraction flow exiting the fishway entrances.

#### Alternatives

We are currently examining two alternatives for the construction of deflectors. Both alternatives are scheduled to result in full installation of 8 deflectors prior to the 1997 outmigration. Both alternatives would limit or terminate BiOp requested spill between August 1 through August 31, 1996, contingent upon contractor-specified needs to begin pre-drilling and dewatering activities involving diver activities to meet the March 15, 1997 completion date.

In the event of forced spill above current hydraulic capacity of the powerhouse (about 88 Kcfs with all six turbine units operable, 76 Kcfs with one turbine unit, 64 Kcfs with two turbine units inoperable), all construction activity in the spillway must be terminated and abandoned until safe conditions resume. To date, Turbine Units 2 and 5 are inoperable at Ice Harbor Dam. All six turbine units are scheduled to be fully operable by mid-May 1996. It is anticipated that the natural reduction of summer flow in the lower Snake River would allow for a full powerhouse capacity operation for the month of August 1996. A potential forced spill event would likely result in equipment damage to the dewatering support structure and unknown effects on the physical condition of fish passed by spill during the event, depending upon the degree of construction activities completed, i.e., possibility of exposed rebar and anchor bolts, or exposed excavated concrete surfaces along the spillbay ogee curve. A forced spill event would result in an unknown amount of delay in construction completion of the 8 deflectors prior to the March 15, 1997, target date.

The first alternative may be preferred by the contractor. Enclosure 1 outlines the schedule and process of installing 8 deflectors in three phases utilizing the two floating nav-lock bulkheads that are currently available. The two bulkheads would be installed first on one side of the spillway, sealing off and dewatering spillbays 2, 3, and 4. Deflectors would then be formed and concrete placed. Bulkhead installation and sealing will require the construction of a complex steel beam support structure (refer to Enclosure 1). This structure incorporates a submerged "table" bolted to the stilling basin floor across the entire length of the spillway. It also includes three sets of scaffolding-type support beams bolted to the face of the respected spillbays. Following concrete finishing during the first phase, the bulkheads would be removed and the process would be replicated on the opposite side of the spillway: sealing off and dewatering spillbays 7, 8, and 9, then deflectors formed and concrete placed. The last phase would include removal of the bulkheads from spillbays 7, 8, and 9. Movement and installation of the bulkheads to spillbays 5 and 6 would then occur, followed by dewatering, then setting forms and concrete placing.

The second alternative is preferred by the Walla Walla District. It may allow for spill during August 1996. The bulkheads with their attachment mechanisms could be removed much more rapidly in the case of a forced spill event. Dewatering for construction could be delayed until after August 31, 1996. This alternative still provides for the completion of 8 deflectors prior to the March 15, 1997 spring/summer chinook smolt outmigration.

The primary difference between the alternatives is the method of dewatering the spillway sections. The second alternative is based upon the concept used in the 1970s to construct the existing deflectors at McNary, Lower Monumental, and Little Goose Dams. New floating bulkheads that act as the form, as well as the dewatering structure, would be fabricated based upon the original 1970s design drawings. These bulkheads would be secured by a tensioning cable system where sealing would be accomplished by hydrostatic pressure. No elaborate steel beam support system would be required, thus allowing a more rapid (down to one day) removal without leaving any supporting structure framework bolted to the spillway face in the event of high forced spill. The time saved in dewatering and deflector construction in relationship to the needed time to construct these bulkheads could delay dewatering to past September 1, 1996. However, there remains a chance that the contractor could not accomplish bulkhead construction in time for implementation and completion of 8 deflectors prior to March 15, 1997.

#### Listed Snake River Salmon Stocks

##### Snake River Sockeye and Spring/Summer Chinook Salmon

Discussion of the migratory patterns of juvenile and adult Snake River sockeye and spring/summer chinook salmon are included in the Biological Assessment for the Operation of the Federal Columbia River Power System for 1994 through 1998.

TABLES 1 and 2 indicate that from 99.0-99.5 percent of the indexed juvenile wild spring/summer chinook and 91.9-97.7 of the O. nerka salmon outmigration would have passed Lower Monumental dam prior to 1 August (FPC 1994, 1995). The PIT-tag database indicates that 100 percent of the wild yearling outmigration had passed Lower Granite Dam by July 23, 1995, (University of Washington CQS World Wide Web Page Realtime Forecaster, 1995). It could take approximately 2-3 more days to arrive in the Ice Harbor forebay, so a few percent reduction may be expected, resulting in greater than 97 percent passage for wild indexed spring/summer chinook and greater than 90 percent passage for wild indexed O. nerka salmon for the 1994 and 1995 indexed population.

## Snake River Fall Chinook Salmon

### Juveniles

Juvenile Snake River fall chinook salmon migrate as subyearlings early in June through mid-August, and peak in numbers at the collector dams in July (Ceballos et al. 1991; and Chapman et al. 1991). Information on the outmigration of Snake River fall chinook salmon at Ice Harbor Dam is limited and is derived from passage at dams immediately upstream on the Snake River and downstream on the Columbia River.

Collections from the first year of operation at Lower Monumental Dam followed the outmigration pattern seen at the other Lower Columbia and Snake River facilities. Total fall chinook salmon collection at Lower Monumental in 1993 was 76,745, with peak collections occurring in July, with 57,016 (74.3 percent) individuals. Total fall chinook salmon numbers declined in August to 12,406 (16.2 percent), in September to 1,225 (1.6 percent), and dramatically in the last week of September continuing through November 1 with average daily collections less than 20 individuals, of which 66.0 percent were of hatchery origin (Spurgeon and Wagner 1994). The combined collection of fall chinook for September and October represented only 2 percent of the total 1993 collection.

McNary Dam on the Lower Columbia River has similar collection patterns to the Snake River dams. Although Snake River fall chinook salmon are only a small portion of the total numbers of fall chinook collected at McNary Dam due to the Hanford Reach subyearling contribution from the mid-Columbia River, both stocks follow similar outmigration patterns. Peaks in fall chinook collection during the years 1982-1993 ranged from June 24 in 1990 to July 22 in 1986 (Ceballos et al. 1991).

Although we expect the fall chinook outmigration at Ice Harbor Dam in 1996 to differ somewhat compared to 1993 and 1995, we expect the run timing to be relatively similar because of the consistency in the outmigration seen in the collections of fall chinook at all the Columbia and Snake River collector projects in 1991 through 1995 (Corps 1992 and 1993, Baxter et al. 1994, Wik et al. 1994, Spurgeon and Wagner 1994, FPC 1994 and 1995).

TABLES 1 and 2 indicate the passage index distribution of juvenile wild fall chinook for 1994 and 1995, with 81.7 percent subyearling passing before August 1 in 1994 and 61.6 percent passing before August 1 during the higher flow year of 1995. This estimate is consistent with a PIT-tag database

analysis (University of Washington CQS World Wide Web Page Realtime Forecaster, 1995). TABLES 1 and 2 suggest that closure of the Ice Harbor spillway during the final month of the BiOp directed spill operation would reroute passage of about one-half of the 5.9-31.8 percent of the annual wild fall chinook outmigration not collected and transported from Lower Granite, Little Goose, and Lower Monumental Dams, assuming a 1:1 spill efficiency. The percentages of total subyearling outmigrant estimates for post-August 1 through October (18.4 percent for 1994 and 38.4 for 1995, TABLES 1 and 2) could be slightly higher when considering unanticipated late migrating or staging phenomena such as the resultant dipping of several thousand subyearling chinook from the Ice Harbor gatewells during the late fall and winter of 1995 after the scheduled smolt sampling season (Dave Hurson, USACE-Walla Walla District, Operations Division, pers. comm., January 1996). With the operation of extended-length screens at Lower Granite Dam during 1996, it is expected that about 67 percent of the fall chinook originating above Lower Granite Dam in the summer would be collected and transported.

#### Adults

Adult Snake River fall chinook enter the lower Snake River in mid- to late-August, and are counted passing through the Ice Harbor Dam ladders until late November, with peak passage occurring in September (Chapman et al. 1991).

#### Effects

Spill operations with deflectors in 8 bays are estimated to provide an additional 20 Kcfs of spill that could be released toward achieving the 80 percent FPE target under the same 120 percent TDG constraint. Operation of the nondeflector outside bays will be eliminated or tightly controlled during forced spill above the estimated new spill cap of 45 Kcfs.

#### Closure of the Ice Harbor Spillway

##### Juveniles

Closure of the spillway will reduce the potential to meet the 80 percent fish passage efficiency (FPE) for subyearling migrant passage during August. The estimated FPE would be solely based upon the fish guidance efficiency

(FGE) assumption of 55-64 percent for spring/summer chinook, 60 percent for O. nerka, and 33-50 percent for fall chinook (Ceballos memo for spring/summer chinook, March 25, 1996). In the case of a high flow event with runoff volumes exceeding the projected powerhouse capacity of 88 Kcfs, all construction activities would be terminated for forced spill. Reinitiation of construction would be coordinated between the Corps, contractor, and NMFS following assessment after the hydrologic event has run the duration of its course.

The primary passage route for smolts past August 1 will be the new juvenile bypass facility, which will be fully operational throughout the 1996 outmigration season (Dave Hurson, USACE-Walla Walla District Operations Division, and Dave Opbroek, USACE-Walla Walla District Construction Division, pers. comms., January and February 1996). Operation of the juvenile screening and bypass system will provide an estimated 33-50 percent FGE based upon BiOp and NMFS survival study calculations using PIT-tag individuals (equating to 33-50 percent FPE in this case where no spill is assumed).

The Corps believes that the closure of the Ice Harbor spillway during August 1 through August 31, 1996, will not adversely affect the listed juvenile Snake River spring/summer chinook salmon stock (estimated less than 0.4 percent of the annual wild outmigrating population) or listed juvenile Redfish Lake sockeye (O. nerka) salmon (estimated at 0.5-1.3 percent of the annual wild outmigrating population) (TABLE 4). The proposed action has the potential to reroute about one-half of an estimated 5.9-31.8 percent of the expected 1996 outmigration population of juvenile wild Snake River fall (subyearling) chinook salmon away from the spillway through the new juvenile bypass system and turbines. For example, 70 percent spill is required with 33 percent FGE to attain 80 percent FPE. The current spill cap for 120 percent TDG equates to 25Kcfs, or 46 percent spill for the BiOp requested total river flow of 55Kcfs for fall chinook. The calculation for effected fall chinook juvenile outmigrants would be 5.9-31.8 percent multiplied by .46 equating to 2.7-14.6 percent.

BiOp operations for juvenile passage beyond August 31, 1996, do not require voluntary spill at Ice Harbor Dam. Closure of the spillway from August 31, 1996, through March 15, 1997, would be consistent with fish passage operations guided by the BiOp.

To date, spill efficiency, spill mortality, nor juvenile bypass facility mortality has not been directly measured at Ice Harbor Dam. Assuming

parameter estimates used for the other lower Snake River dams of 1:1 spill efficiency, 2 percent direct spill mortality with no gas bubble trauma related mortality, and 2 percent bypass mortality, an estimate of the increased amount of turbine mortality can be calculated. Applying estimated FGE ranges for Ice Harbor Dam of 50-73 percent for spring/summer and sockeye salmon and 33-50 percent for fall chinook salmon (TABLE 3) to the estimated range for turbine mortalities of 8-15 percent, then mortality due to increased turbine passage is estimated to be 0.002-0.004 percent of the annual wild spring/summer chinook salmon outmigrating population, 0.002-0.02 percent of the annual wild sockeye (*O. nerka*) salmon outmigrating population, and 0.08-1.1 percent of the annual wild fall chinook salmon outmigrating population.

Operation of extended-length screens at Lower Granite Dam during 1996 is expected to remove about 60 percent of the fall chinook smolts originating above Lower Granite Dam for collection and barge or truck transport. This adjusted routing calculates to an estimated difference in turbine mortality of 0.8-1.1 percent using an estimated 15 percent turbine mortality or 0.08-0.1 percent using and estimated 8 percent turbine mortality (TABLE 4).

### Adults

Adult Snake River fall chinook salmon will not be adversely affected by the proposed in-water construction activities, because spill generally detracts from adult passage conditions. There is potential for some minor near-field delay in ladder approach and entrance during low river flows. The historical adult ladder attraction flow conditions used before the BiOp requested spill operations will serve as the initial default operation.

Preliminary results from the Ice Harbor and John Day Dam general models for partial spillway installation of deflectors had been discouraging for the development of suitable hydraulic conditions in the tailrace. The creation of strongly unstable submerged lateral flow across the channel was created by the operation of nondeflector bays influencing adjacent deflector bays.

Recent testing for adult patterns with the Ice Harbor general model (scale 1:55) running 25 to 60 Kcfs spill indicated that acceptable passage conditions exist with 8 deflectors. Hydraulic conditions for adult passage and a small incremental reduction in TDG could improve with training wall extensions and deflectors in spillbays 1 and 10. Construction of additional

deflectors and/or retaining wall extensions would require time beyond the March 15, 1997, target completion date. A second year would be required to fully complete the project.

A consequence of this partial deflector and retaining wall installation would be uncertainty associated with mechanical- and TDG-related effects to adult migrants of all salmonid stocks while operating for an entire fish passage season under unmeasured risks to passage delay and survival. Operational effects to juvenile and adult migrants could be assumed to be no more negative than those nondeflector bay operations that occurred unmeasured at Little Goose and Lower Monumental Dams since the late-1970s. Resultant hydraulic conditions would not be optimal according to more recent knowledge learned from 1993-95 dam operations with voluntary spill and physical model studies. Voluntary spill patterns for adult and juvenile salmon passage during the 1997 outmigration would be highly weighted toward the use of deflector spillbays.

### Preventative Measures

#### Juveniles

The juvenile bypass system with submerged traveling screens will be operated to system capacity with all tainter gates on seal to prevent juvenile salmonids from entering the dewatered spillway until construction is complete in March 1997 or an overgeneration hydrologic event forces involuntary spill.

In the event that an hydrologic event results in overgeneration spill above the currently proposed hydraulic capacity of the powerhouse, all construction activity in the spillway will be terminated and abandoned for worker safety until the hydrologic event has run its course. This may result in equipment damage and unknown effects on the physical condition of the fish passing through spill, depending upon the degree of construction activities completed, i.e., possibility of exposed rebar and anchor bolts, or exposed excavated concrete surfaces along the spillbay ogee curve. This forced spill scenario would result in an unknown amount of delay in construction completion of deflectors prior to the March 15, 1997, target date. Reinitiation of repair and construction will be coordinated between the Corps, contractor, and NMFS.

## Adults

### Floating Bulkhead Placement

No reports of any fish trapped behind bulkheads during dewatering of the spillbays for deflector construction during the 1970s are known. As a precaution to prevent stranding of any fish, the tainter gates will be closed during the previous night for a minimum of 8 hours to reduce attraction of fish into the work area before installing the bulkheads. Adults of any salmonid or sportfish species that may be discovered trapped upon dewatering of the isolated work area will be safely removed by a project biologist prior to total dewatering and released to pass upstream through an adult ladder.

### Adult Ladder Entrance Attraction during Construction

The historical adult ladder attraction conditions coordinated and used for no spill operations will serve as the default operation.

### Additional Impacts

Although the proposed construction work will be in the dewatered spillway, there is a possibility that concrete and machinery oils may enter the lower Snake River due to the close proximity of the work area to the tailrace. Debris from construction activities may fall to the bottom of the dewatered spillway, which may eventually drain into the river and across probable fall chinook redds. Adequate powerhouse flows should be available under maximum powerhouse flow routing to provide suitable velocities across the powerhouse side of the tailwater channel for spawning activity. In 3 years of redd surveys, Battelle-PNL have failed to locate any redd construction activity below Ice Harbor Dam (Dauble et al. 1994, 1995). We will require the contractor to provide methods of confining construction debris and to prevent the direct entry or seepage of unsuitable materials into the Snake River.

Underwater drilling and hammering for anchor and structural bolts and concrete removal to form the radius section may cause minor delay or avoidance of adult chinook salmon to enter the ladder entrance nearest the activity. Monitoring experience with vibratory hammer operation during the University of Idaho adult studies indicated no effects with adult steelhead (Rudy Ringle, pers. comm., March 1996).

Summary

This letter is provided as coordination with the NMFS for the proposed action of constructing flow deflectors in the centered spillbays at Ice Harbor Dam. The Corps believes that the closure of the Ice Harbor spillway from August 1, 1996, through March 15, 1996, would not adversely affect listed Snake River salmon stocks beyond those assumed impacts and risks considered by NMFS in their BiOp for 1994-98 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years.

SNAKE RIVER SOCKEYE AND SNAKE RIVER SPRING/SUMMER CHINOOK SALMON stocks would not likely be adversely affected by the proposed closure of the spillway after August 1, 1996, because only a few individuals representing the receding tail of the total annual wild passage population distribution would be present in, or passing through, the area during the proposed activity period. The proposed action has the potential to reroute about 46 percent of an estimated 5.9-31.8 percent of the expected 1996 outmigrating population of juvenile wild Snake River fall chinook salmon away from the spillway through the new juvenile bypass system and turbines. Applying estimated FGE ranges for Ice Harbor Dam of 50-73 percent for spring/summer and sockeye salmon and 33-50 percent for fall chinook salmon to the estimated range for turbine mortalities of 8-15 percent, mortality due to increased turbine passage is estimated to be 0.002-0.004 percent of the annual wild spring/summer chinook salmon outmigrating population, 0.002-0.02 percent of the annual wild sockeye salmon outmigrating population, and 0.08-1.1 percent of the annual wild fall chinook salmon outmigrating population.

Please contact me or Chris Pinney, Walla Walla District Fishery Biologist, at 509-527-7284, if there are any questions. Mr. Jim Athearn, at 503-326-2835, remains the North Pacific Division's ESA coordinator.

Sincerely,

*for Guy Phoades*

James S. Weller  
Lieutenant Colonel, Corps of Engineers  
District Engineer

Enclosures

Copy Furnished:

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TABLE 1. Monthly indexed estimates of smolt passage of wild Snake River yearling and subyearling chinook and O. nerka salmon passing at Lower Monumental dam during 1994, as derived from Fish Passage Center weekly report indices (1994).

1994						
	Yearling		Subyearling		O. nerka	
	Number	Percent	Number	Percent	Number	Percent
APR22	25467	23.1	30	0.4	50	1.8
MAY	76465	69.5	1096	14.1	1913	68.2
JUN	2448	2.2	2450	31.5	320	11.4
JUL	4587	4.2	2780	35.7	294	10.5
AUG	302	0.3	462	5.9	14	0.5
SEP	722	0.7	839	10.8	84	3.0
OCT20	76	0.07	131	1.7	128	4.6
APR-OCT	110067		7788		2803	
Pre-AUG 1		99.0		81.7		91.9
AUG 1-31		0.3		5.9		0.5
Post-Aug 1		1.1		18.4		8.1
Post-Aug31		0.8		12.5		7.6

TABLE 2. Monthly indexed estimates of smolt passage of wild Snake River yearling and subyearling chinook and *O. nerka* salmon passing at Lower Monumental dam during 1995 as derived from Fish Passage Center weekly report indices (1995).

1995						
	Yearling		Subyearling		<i>O. nerka</i>	
	Number	Percent	Number	Percent	Number	Percent
APR	43493	18.0	0	0.0	303	11.6
MAY	158190	65.3	118	1.3	1644	63.1
JUN	34842	14.4	759	8.5	429	16.5
JUL	4405	1.8	4653	51.8	170	6.5
AUG	1017	0.4	2860	31.8	33	1.3
SEP	171	0.08	478	5.3	12	0.5
OCT	47	0.02	116	1.3	16	0.6
APR-OCT	242165		8984		2607	
Pre-AUG 1		99.5		61.6		97.7
AUG 1-31		0.4		31.8		1.3
Post-Aug 1		0.5		38.4		2.4
Post-Aug31		0.1		6.6		1.1

TABLE 3. Assumed FGE range for analysis presented.

	Yearling Chinook	Sockeye	Subyearling Chinook
Lower Granite	60-74	48	31
Little Goose	45-55	60	31
Lower Monumental	45-55	60	31
Ice Harbor	55-73	55-73	33-50

CAP 4/3/1996									
TABLE 4. Calculations for estimated turbine mortality of seasonal proportions of spring/summer chinook, sockeye, and fall chinook salmon resulting from BIOp derivation for terminating spill 1-31 August 1996 at Ice Harbor Dam.									
Adjusted IHR % total wild by % Total wild population entering									
% Passage 1-31 August Ice Harbor 1-31 August									
% Total wild population entering Ice Harbor									
Low FGE upstream High FGE upstream									
CH1									
	0.287	0.192	0.0035	0.0009835	0.000672	0.000672			
O. nerka	0.215	0.215	0.005	0.001075	0.000672	0.000672			
			0.005	0.001075					
			0.013	0.002795					
			0.013	0.002795					
CHO	0.329	0.329	0.059	0.019411					
			0.059	0.019411					
			0.318	0.104622					
			0.318	0.104622					
TABLE 4. cont.									
% Total wild pop passing Ice Harbor turbines									
Low U/S FGE High U/S FGE									
Ice Harbor % turbine (1-FGE)	0.55	0.45	0.000442575	0.0003024					
	0.73	0.27	0.000265545	0.00018144					
	0.55	0.45	0.00048375						
	0.73	0.27	0.00029025						
	0.55	0.45	0.00125775						
	0.73	0.27	0.00075465						
	0.33	0.67	0.01300537						
	0.5	0.5	0.0097055						
	0.33	0.67	0.0700674						
	0.5	0.5	0.052311						
TABLE 5.									
RUN #1: 25Kd's spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 6.									
RUN #2: 25Kd's spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 7.									
RUN #3: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 8.									
RUN #4: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 9.									
RUN #5: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 10.									
RUN #6: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 11.									
RUN #7: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 12.									
RUN #8: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 13.									
RUN #9: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			
	0.06	0.09	0.09	0.16	0.11	CHO			
% pass	0.1	0.05	0.05	0.05	0.1	CH1			
Turbine	0.06	0.06	0.06	0.06	0.06	O. nerka			
	0.12	0.09	0.16	0.16	0.22	CHO			
TABLE 14.									
RUN #10: No Spill									
Low FGE High FGE									
AI IHR									
% pass	0.07	0.05	0.05	0.05	0.07	CH1			
Spill	0.05	0.05	0.05	0.05	0.05	O. nerka			
	0.15	0.15	0.15	0.15	0.15	CHO			
% pass	0.12	0.09	0.09	0.09	0.12	CH1			
bypass	0.1	0.1	0.1	0.1	0.1	O. nerka			

## **DRAFT**

### **FINDING OF NO SIGNIFICANT IMPACT**

#### **ICE HARBOR DAM SPILLWAY DEFLECTORS**

#### **FRANKLIN AND WALLA WALLA COUNTIES, WASHINGTON**

The Corps of Engineers proposes to modify the spillway of Ice Harbor Dam by constructing deflectors on up to ten of the spillbays and extending one or both training walls. The dam is located on the lower Snake River at River Mile 9.5, near Pasco, Washington. The purpose of the deflectors is to reduce the amount of dissolved gas produced as river flows are passed through the dam spillway. High concentrations of total dissolved gas (TDG) can injure or kill juvenile and adult salmon, as well as resident fish and other aquatic organisms. The need for TDG abatement is of immediate concern to the region because of declining salmon populations and the listing of three Snake River salmon stocks (spring/summer chinook, fall chinook, and sockeye) as either threatened or endangered under the Endangered Species Act. In their March 1995 Biological Opinion on Operation of the Federal Columbia River Power System, under Reasonable and Prudent Measures Intermediate Term Action No. 18, the National Marine Fisheries Service requested that spillway modifications for gas abatement at Ice Harbor Dam be completed as soon as possible, contingent on the results of TDG abatement evaluations in 1995 and 1996. The Corps proposes to construct eight deflectors in 1996/1997 and the remaining two deflectors and the training wall extension(s) in 1997/1998 to comply with NMFS' request.

The Corps evaluated several other alternative methods of reducing TDG. These included modifying the stilling basin, raising the tailrace, making operational changes in the spill pattern, and eliminating voluntary spill of water for fish passage. These alternatives were removed from further consideration because they are still being investigated as part of the on-going gas abatement studies and may take between 4 and 10 years to implement. The Corps identified only one alternative, spillway deflectors, that would provide meaningful reduction in TDG and could be implemented in time for the 1997 outmigration. Therefore, constructing and operating the spillway deflectors is the Corps' selected action.

Construction and operation effects of the proposed spillway deflector project are addressed in the project environmental assessment. Effects of the facilities are largely focused on impacts to the aquatic environment. Construction of the spillway deflectors would have minimal impacts on aquatic resources in the vicinity of the dam. No important fish habitat would be disturbed by the construction and fish and other organisms in the river would easily avoid the construction activities. Operation of the spillway deflectors is expected to decrease TDG when water is being spilled, which would improve in-water conditions for salmon as well as other aquatic organisms. The Corps has estimated that installing deflectors at Ice Harbor Dam could possibly reduce dissolved gas supersaturation by up to 5- to 10-percent for spills flows up to 60,000 cubic feet per second (cfs).

This project has been coordinated with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Washington Department of Fish and Wildlife, other concerned state and Federal agencies, tribes, and the public. The project is in compliance with all applicable laws and regulations. In view of the information provided by these sources, the environmental assessment, and comment letters, I find that the proposed action would not result in significant impacts and that an environmental impact statement is not required.

DATE: \_\_\_\_\_

\_\_\_\_\_  
James S. Weller  
Lieutenant Colonel, Corps of Engineers  
District Engineer



DEPARTMENT OF THE ARMY  
NORTH PACIFIC DIVISION, CORPS OF ENGINEERS  
P.O. BOX 2870  
PORTLAND, OREGON 97208-2870

Reply to  
Attention of:

CENPD-ET-PG (1130)

22 June 1995

MEMORANDUM FOR

Commander, Portland District (CENPP-PE-DS)  
✓ Commander, Walla Walla District (CENPW-EN-DB-HY)

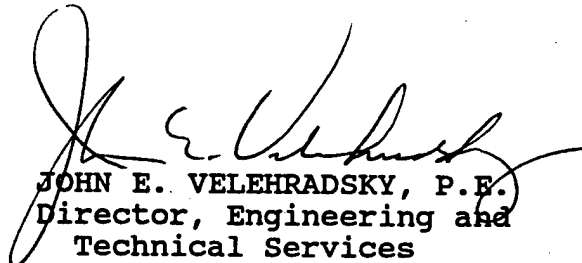
SUBJECT: Ice Harbor Dam and John Day Dam Spillway Deflector  
Studies

1. Reference:

- a. CENPD-PE-GE 1st Endorsement, dated 17 January 1995,  
subject: Ice Harbor Dam, Spillway Deflector Letter Report,  
October 1994.
- b. National Marine Fisheries Service Biological Opinion,  
dated 2 March 1995, Reasonable and Prudent Measure #18.
- c. CENPD-ET-PG Memorandum, dated 12 June 1995, subject:  
Ice Harbor Dam and John Day Dam Spillway Deflector Studies.

2. Schedules, including design memorandum, model studies plans  
and specifications and construction should be provided. This  
work will need to be programmed separately from the gas abatement  
study.

FOR THE COMMANDER:

  
JOHN E. VELEHRADSKY, P.E.  
Director, Engineering and  
Technical Services



DEPARTMENT OF THE ARMY  
NORTH PACIFIC DIVISION, CORPS OF ENGINEERS  
P.O. BOX 2870  
PORTLAND, OREGON 97208-2870

Reply to  
Attention of:

CENPD-ET-PG (1130)

JUN 12 1995

MEMORANDUM FOR

Commander, Portland District, ATTN: CENPP-PE-DS  
~~Commander, Walla Walla District, ATTN: CENPW-EN-DR-HV/~~

SUBJECT: Ice Harbor Dam and John Day Dam Spillway Deflector  
Studies

1. Reference:

a. CENPD-PE-GE 1st Endorsement dated 17 January 1995,  
subject: Ice Harbor Dam, Spillway Deflector Letter Report,  
October 1994.

b. National Marine Fisheries Service Biological Opinion  
dated 2 March 1995, Reasonable and Prudent Measure #18.

2. In order to implement NMFS's Biological Opinion  
(reference 1b) and subsequent CENPD Record of Decision  
(10 March 1995) more efficiently, the spillway deflector analysis  
and design are to be performed for John Day and Ice Harbor dams  
in separate studies from the gas abatement program. This is  
contrary to previous direction provided by this office  
(reference 1a). This work should be undertaken expeditiously,  
moving into a feature design memorandum immediately and into  
plans and specifications to allow for construction completion as  
soon as possible.

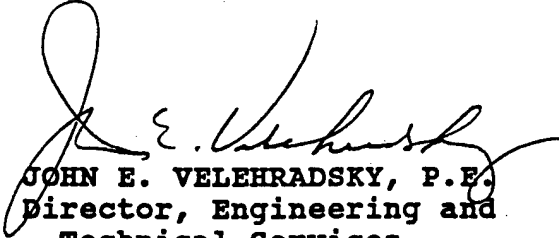
3. Pertinent findings from the gas abatement study should be  
incorporated in these designs as the information becomes  
available, however time is of the essence and implementation of  
spillway deflectors should precede unimpeded by the final  
analysis of the gas abatement program.

CENPD-ET-PG

SUBJECT: Ice Harbor Dam and John Day Dam Spillway Deflector  
Studies

4. Regarding the CENPD comments in the 17 January 95 endorsement (reference 1a) Walla Walla District should provide a response reflecting which comments are no longer pertinent given the above guidance. Upon incorporation of remaining comments, the Ice Harbor Dam, Spillway Deflector Letter Report can be approved and provided to the fishery agencies for their review.

FOR THE COMMANDER:



JOHN E. VELEHRADSKY, P.E.  
Director, Engineering and  
Technical Services

CENPD-PE-GE (CENPW-EN-DB-HY/17 Oct 94) (1110) 1st End  
Mr. McCartney/aj/503-326-3858  
SUBJECT: Ice Harbor Dam, Spillway Deflector Letter Report,  
October 1994

CDR, North Pacific Division, Corps of Engineers, P.O. Box 2870,  
Portland, OR 97208-2870  
JAN 17 1995

FOR CDR, Walla Walla District, ATTN: CENPW-EN-DB-HY

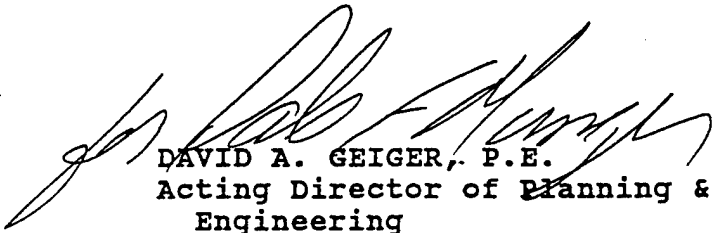
1. You are commended for preparation of this excellent report. However, the Dissolved Gas Abatement study will be the primary vehicle to address this problem at the (4) Snake River, and (4) lower Columbia River projects. The letter report should be revised to reflect the benefits of including the Ice Harbor effort in the Gas Abatement study. You are reminded that the National Marine Fisheries Service (NMFS), in their 1994-98 Biological Opinion, requested a report by 31 January 1995. While we do not know at this time whether NMFS will accept the proposed approach, your report will provide a logical alternative that they will hopefully give strong consideration to. Similar guidance will be given to CENPP regarding John Day Dam by copy of this memorandum.

2. The alternative flip lip configurations identified in the subject report are to be evaluated along with other structural modifications in the Dissolved Gas study. Previously approved model studies for Ice Harbor will facilitate development of the optimum gas abatement alternative.

3. The enclosed NPD comments are to be used in the study of gas abatement alternatives for Ice Harbor.

FOR THE COMMANDER:

2 Encls  
1 wd  
Added 1 encl  
2. CENPD cmts.

  
DAVID A. GEIGER, P.E.  
Acting Director of Planning &  
Engineering

CF: CENPP-EN

## CE NPD COMMENTS

1. Decisions made in the mid-1970's to postpone installation of deflectors at IHR need to be reviewed in more depth than presented. The subject of expected reduction in quantity and frequency of spill in particular should be better documented. The Corps has accumulated a sizable amount of flow and TDG data that should allow for detailed statistical analysis. Changes in spill brought about by the Power Planning Council's Fish and Wildlife Program and other regional agreements should be tabulated and analyzed, using actual spill and TDG data.
2. CENPW staff estimated possible TDG reductions at IHR based on extrapolated data collected at LMN. While we support this approach, we believe it should also include estimating TDG ranges based on current spill levels at IHR. Also, conspicuous by its absence is any reference to and application of a mathematical model such as GASSPILL. Here is a potential means for developing other estimates of TDG reduction, taking into account changes in the dimensions of the stilling basin; spill amounts, and total flows (and hence submergence levels). GASSPILL accounts for all the relevant elements, including spill, total flow incoming TDG, head drop, water temperature, etc. Therefore, use of a mathematical model to assess local as well as system TDG impact should be made to supplement methods presented in the letter report. Impacts may not be quantified in absolute terms but at least in relative terms for comparison purposes.
3. There is a good section on the impacts of TDG on anadromous fish, including quantification of these impacts in the CRISP model. Expand this section further by estimating the range of improvement in fish survival with the deflectors in place. Improvements should be estimated both at the project and system level, assuming different flow and spill conditions.
4. The options considered are mostly concentrated on the location of the deflectors with respect to individual spillway bays. Two other options are also of interest. The first additional option is to investigate ways to improve FGE so that the required spill to achieve 80% FPE is reduced before the current 25,000 cfs or any other spill level commensurate with a relaxed TDG standard. Is this (indirect) solution feasible and if so, at what cost? The second option is to look at a side-bypass spillway at one or both ends of the dam. This would include two or more intermediate mini stilling basins similar in concept to stair-steps used on conventional fish ladders. Is this a feasible solution?
5. The section on NEPA and EIS requirements should also address other elements. These include coordination with cooperating agencies; NEPA process applied to this project; and interface with System Configuration and Dissolved Gas Abatement studies.

Enclosure

6. The letter report should provide a short section on project funding. Is cost-sharing an issue? What is the funding level required and the process through which this project would be implemented.

Enclosure

## **APPENDIX E**

### **Cost Estimates**

PROJECT: SPILLWAY DEFLECTORS  
LOCATION: ICE HARBOR LOCK AND DAM

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE DESIGN MEMORANDUM #34, DATED: 6 SEPT 96  
DISTRICT: Walla Walla  
P.O.C.: KIM CALLAN, CHIEF, COST ENGINEERING

ACCOUNT NUMBER	FEATURE DESCRIPTION	EFFECTIVE PRICING LEVEL: 1 OCT 96				AUTHORIZ./BUDGET YEAR: 1998				EFFECT. PRICING LEVEL: 1 OCT 97				.....FULLY FUNDED ESTIMATE.....			
		COST (\$K)	CNTG (\$K)	CNTG (%)	TOTAL (\$K)	COST (\$K)	CNTG (\$K)	CNTG (%)	TOTAL (\$K)	COST (\$K)	CNTG (\$K)	CNTG (%)	TOTAL (\$K)	SPENT THRU FY 95 (\$K)	COST (\$K)	CNTG (\$K)	FULL (\$K)
04--	DAMS GOVERNMENT FURNISH SERVICES	6,207	621	10%	6,828	6,375	637		7,012	6,375	637		7,012		6,375	637	7,012

TOTAL CONSTRUCTION COSTS =	6,207	621	10%	6,828	6,375	637		7,012	6,375	637		7,012			6,375	637	7,012
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01---	LANDS AND DAMAGES																
18---	CULTURAL RESOURCES																
21---	RECONNAISSANCE STUDIES																
22---	FEASIBILITY STUDIES																
30---	PLANNING, ENGINEERING & DESIGN	1,458	146	10%	1,604	1,498	149		1,647	1,498	149		1,647		1,498	149	1,647
31---	CONSTRUCTION MANAGEMENT	620	62	10%	682	637	64		701	637	64		701		637	64	701

TOTAL PROJECT COSTS =	8,285	829	10%	9,114	8,510	850		9,360	8,510	850		9,360			8,510	850	9,360
-----------------------	-------	-----	-----	-------	-------	-----	--	-------	-------	-----	--	-------	--	--	-------	-----	-------

THIS TPCS REFLECTS A PROJECT COST CHANGE OF \$

TOTAL FEDERAL COSTS = >

TOTAL NON-FEDERAL COSTS = >

DISTRICT APPROVED: \_\_\_\_\_

DISTRICT APPROVED DATE: \_\_\_\_\_

CHIEF, COST ENGINEERING, Kim Callan  
CHIEF, REAL ESTATE, Richard Carlton  
CHIEF, PLANNING, Doug Frel (Acting)  
CHIEF, ENGINEERING, Surya Bhamidipaty  
CHIEF, OPERATIONS, Wayne John  
CHIEF, CONSTRUCTION, Gary Willard  
CHIEF, CONTRACTING, Jackie Anderson  
PROJECT MANAGER, (Enter Name)  
DDE (PMI), Mark Charlton

THE MAXIMUM PROJECT COST IS > \$

DIVISION APPROVED: \_\_\_\_\_

CHIEF, COST ENGINEERING  
DIRECTOR, REAL ESTATE  
CHIEF, PROGRAMS MANAGEMENT  
DIRECTOR OF PPMD

DIVISION APPROVED DATE: \_\_\_\_\_



7777 CONTRACT 7777														*** TOTAL CONTRACT COST SUMMARY ***														PAGE 2 OF 2																																													
PROJECT: SPILLWAY DEFLECTORS LOCATION: ICE HARBOR LOCK AND DAM														THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE DESIGN MEMORANDUM #34, DATED: 6 SEPT 96																																																											
CURRENT MCACES ESTIMATE PREPARED: 6 SEPT 96 EFFECTIVE PRICING LEVEL: 1 OCT 96														DISTRICT: Walla Walla P.O.C.: KIM CALLAN, CHIEF, COST ENGINEERING																																																											
ACCOUNT														AUTHORIZ./BUDGET YEAR: 1998																																																											
NUMBER														EFFECT. PRICING LEVEL: 1 OCT 97																																																											
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SPILLWAY DEFLECTORS - BAYS #2 THROUGH 9																																																																									
ICE HARBOR FEATURE DESIGN MEMORANDUM NO 34																																																																									
TOTAL CONSTRUCTION COSTS ==														6,207														637														7,012														7,012																	
01---	LANDS AND DAMAGES																																																																								
22---	FEASIBILITY STUDIES																																																																								
30---	PLANNING, ENGINEERING & DESIGN																																																																								
2.5%	Project Management													155														16														175														175																	
1.0%	Planning & Environmental Compliance													62														6														64														64																	
15.0%	Engineering & Design													931														93														1,024														966																	
1.0%	Engineering Tech Review & VE													62														6														64														64																	
1.0%	Contracting & Reprographics													62														6														64														64																	
3.0%	Engineering During Construction													186														19														191														191																	
31---	CONSTRUCTION MANAGEMENT													620														62														637														637																	
10.0%																																																																									
TOTAL COSTS ==														8,285														829														10%														9,114														8,510			
DAMS																																																																									
06.2--	GOVERNMENT FURNISH MATERIALS																																																																								
30---	PLANNING, ENGINEERING & DESIGN																																																																								
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TOTAL GFS COSTS == >																																																																									
18---	MISC COSTS FOR ALL PROJECTS																																																																								
CULTURAL RESOURCES																																																																									
30---	ANOTHER MISC E & D COSTS																																																																								

Sat 07 Sep 1996  
Eff. Date 06/20/96

PROJECT INFL16:

U.S. Army Corps of Engineers  
Eight Spillway Deflectors Bulkh. - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96, "DH" 's Bulkhead

TIME 01:08:17

TITLE PAGE 1

Eight Spillway Deflectors Bulkh.  
Ice Harbor Lock & Dam  
Snake River  
Pasco, Washington  
\*\*\* PRICE LEVEL 1 OCT 96 \*\*\*

Designed By: Walla Walla District COE  
Estimated By: Karl Pankaskie

Prepared By: Cost Engineering Branch  
Kim Callan, Chief

Preparation Date: 06/20/96  
Effective Date of Pricing: 06/20/96  
Est Construction Time: 230 Days

Sales Tax: 7.95%

This report is not copyrighted, but the information  
contained herein is For Official Use Only.

M C A C E S G O L D E D I T I O N  
Composer GOLD Software Copyright (c) 1985-1994  
by Building Systems Design, Inc.  
Release 5.30A

LABOR ID: EH4S96

Currency in DOLLARS

CREW ID: NAT948

UPB ID: NAT95A

PROJECT DESCRIPTION - THIS ESTIMATE IS FOR THE SYSTEM SHOWN IN THE "DMH". This estimate consists of costs to install six (#3 through #8) and two optional (#2 and #9) concrete spillway deflectors with seven pier extensions on the face of the existing Ice Harbor spillways bays. This face is 470 linear feet in length. All deflectors and most of the pier extensions are below water, therefore dewatering will be required for all concrete placements. Diving will be done in depths of less than fifty feet.

Note: The adjacent pier extensions must be completed before the spillway deflectors are installed.

First, the floating plant drills under water holes for the rebar dowels and the bars are set in place for the pier and then the spillway. Then the metal bulkheads form supports are placed, anchored under water, and sealed under water. Then part of the existing spillway concrete is removed and deposited off site. The spillway gate leaking water must be channeled to one side and over the work area. The dowel grouting, concrete prep, standard reinforcement, and concrete work are then accomplished. The area is watered up and the bulkheads are removed. Anchor bolts are cut off underwater; concrete is patched up and painted underwater. Then this process is repeated for the next all stages.

#### BASIS OF DESIGN

This estimate is for bid specifications and drawings, dated for bid opening on 6/20/96.

#### CONSTRUCTION SCHEDULE

The contractor shall commence work under this contract within 10 calendar days of receiving the notice to proceed. Then the contractor should prosecute said work diligently, and complete the entire work ready for use, within the time frame and not later than the date listed below.

1. The spillway will be shut down on September 1, 1996 and in water work can begin.
2. Complete submittal shall be submitted 30 day after notice to proceed.
3. Spillway deflectors #4, #5, #6 and #7 shall be completed by December 15, 1996.
4. Any two of #4 through #7 shall be completed by November 1, 1996.
5. Spillway deflectors #3 and #8 shall be completed by January 20, 1997.
6. Optional spillway deflectors #2 and #9 shall be completed by March 1, 1997.
7. Final cleanup and demobilization shall be completed by February 4, 1997 or March 16, 1997.

#### OVERTIME

This estimate contains overtime to complete the project using three shifts seven days a week. The reason for the overtime is to get the work done in the non spill period. See construction schedule for more information.

#### SUBCONTRACTING PLAN

The following are subcontractor on this project:  
Diving Subcontractor (DV)  
Concrete Pumping Subcontractor ( ) (Rental)

Sat 07 Sep 1996  
Eff. Date 06/20/96  
PROJECT NOTES

PROJECT INFL16: U.S. Army Corps of Engineers  
Eight Spillway Deflectors Bulkh. - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96, "DW" 's Bulkhead

TIME 01:08:17

TITLE PAGE 3

Floating Plant Subcontractor ( ) (Rental)  
Saw Cutting Subcontractor (SC)

It is assumed that the prime contractor will do the rest of the work.

#### PROJECT CONSTRUCTION

##### SITE ACCESS

The project site is located on Ice Harbor Lock and Dam approximately 20 miles from Pasco, Washington. The work site access is very difficult because it is off either floating barges or far away from the power house road or below the very high spillway bridges. Concrete pumping can be done off the spillway bridges or a pump line can be constructed from the power house to the placements.

##### BORROW AREAS

No borrow sources are needed. Concrete comes from a commercial source near Pasco, Washington.

##### DISPOSAL PLACE

There is a Corps concrete disposal site close by where the concrete debris can be buried.

##### CONSTRUCTION METHODOLOGY

The construction methodology is standard concrete construction off barges. The dewatering scheme is unique and untried.

##### UNUSUAL CONDITIONS (Soil, Water, Weather)

There are no unusual conditions other than dewatering the work area and working off the floating barges. Note most of the work is accomplished in the cold weather seasons.

##### UNIQUE TECHNIQUES OF CONSTRUCTION

Underwater divers will install anchor bolts and dowel rebar, remove concrete and install dewatering structures and platforms. The water is murky which has and negative effect on production. The dewatering structure is held together mainly by water pressure and anchor bolts.

##### EQUIPMENT AND LABOR AVAILABILITY & DISTANCE TRAVELED

This estimate uses Davis Bacon labor rates for Franklin County, revision number 5 dated 5/17/96. See labor spread sheet for the development of labor costs used in the estimate. Equipment rates used are from EP 1110-1-8, Volume 8, August 1995. Fuel prices have been increased to cover the rise in fuel prices. FCCM has been change to the current rate.

##### ENVIRONMENTAL CONCERNS

The removed concrete must be disposed of in an landfill. Waste water needs to be PH tested. If waste water is acceptable it can be put back into the river. If the PH is too high or too low the water is removed.

##### ACQUISITION PLAN

The project will be acquired by the bidding process only. No other items will be acquired by purchase order(s) at this time.

LABOR ID: EWAS96 EQUIP ID: NAT95A

Currency in DOLLARS

CREW ID: NAT94B UPB ID: NAT95A



SUMMARY REPORTS

SUMMARY PAGE

PROJECT INDIRECT SUMMARY - CSI ITEM.....	1
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DETAILED ESTIMATE

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Sat 07 Sep 1996  
Eff. Date 06/20/96

PROJECT IHFL16: U.S. Army Corps of Engineers  
Eight Spillway Deflectors Bulkhead - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96, "DMU's Bulkhead"  
\*\* PROJECT INDIRECT SUMMARY - CSI ITEM \*\*

TIME 01:08:17

SUMMARY PAGE 1

	QUANTITY	UOM	TOTAL DIRECT	FOOH	MOOH	PROF	PL & PD	BOND	TOTAL COST	UNIT COST
01 CONSTRUCT SPILLWAY DEFLECTOR										
01.06 FISH AND WILDLIFE FACILITIES										
01.06.01 FISH FACILITIES AT DAMS										
01.06.01.44 FISHWAYS AND FISH LADDERS										
01.06.01.44.001- MOBILIZATION & DEMOBILIZATION										
01.06.01.44.001- 01AA Mobilization			30,928	6,576	1,500	0	0	255	39,259	
01.06.01.44.001- 01AB Mobilization Floating Plant			26,988	5,738	1,309	0	0	222	34,257	
01.06.01.44.001- 01AD Demobilization			31,328	6,661	1,520	0	0	258	39,766	
01.06.01.44.001- 01AE Demobilization Floating Plant			26,988	5,738	1,309	0	0	222	34,257	
TOTAL MOBILIZATION & DEMOBILIZATION			116,231	24,712	5,638	0	0	958	147,539	
01.06.01.44.003- DEWATERING SPILLWAY GATE AREAS										
01.06.01.44.003- A00- BULKHEAD FAB. COSTS										
01.06.01.44.003- E00- DEWATER OF PIER EXTENSIONS	1.00	TT	0	0	0	0	0	0	0	0.01
01.06.01.44.003- N00- DEWATER SPILLWAY GATES D-Stream	1.00	TT	0	0	0	0	0	0	0	0.01
01.06.01.44.003- N01F Install & Remove Spillway Stoplog	6.00	SET	91,812	19,520	4,453	0	0	757	116,543	19,423.76
01.06.01.44.003- N01G Cost to Operate Sump Pump	6.00	SET	1,850	393	90	0	0	15	2,348	391.38
01.06.01.44.003- 000- DEWATERING IN FRONT OF SPILLWAY	1.00	TT	0	0	0	0	0	0	0	0.01
TOTAL DEWATERING SPILLWAY GATE AREAS			93,662	19,914	4,543	0	0	772	118,891	19815.15
01.06.01.44.003A DEWATERING IN FRONT OF SPILLWAY										
01.06.01.44.003A A01A BULKHEAD - STAGE 1										
01.06.01.44.003A A05C End Support, Pier #9	1.00	EA	45,477	9,669	2,206	0	0	0	57,726	57726.39
01.06.01.44.003A A05F Center Support, Bay #8	1.00	EA	61,712	13,121	2,993	0	0	375	78,335	78335.11
01.06.01.44.003A A05I End & Side Support, Pier #6	1.00	EA	59,106	12,567	2,867	0	0	487	75,026	75025.93
01.06.01.44.003A A05M Bottom Support, Bays #9 -> #6	8.00	EA	410,029	87,177	19,888	0	0	3,379	520,473	65059.09
01.06.01.44.003A A05P Gout Supports Plates	80.00	EA	13,636	2,899	661	0	0	112	17,308	216.36
01.06.01.44.003A A05R Set Floating Bulkheads, B #9->#7	2.00	EA	1,358	289	66	0	0	11	1,724	861.79
01.06.01.44.003A A05R Pump out Water, Bays #7 -> #9	560200.00	GAL	14,394	3,060	698	0	0	119	18,272	0.03
01.06.01.44.003A B01A BULKHEAD - STAGE 2										
01.06.01.44.003A B05C End Support, Pier #1	1.00	EA	45,477	9,669	2,206	0	0	0	57,726	57726.39
01.06.01.44.003A B05F Center Support, Bay #3	1.00	EA	61,712	13,121	2,993	0	0	375	78,335	78335.11
01.06.01.44.003A B05I End & Side Support, Pier #4	1.00	EA	59,106	12,567	2,867	0	0	487	75,026	75025.93
01.06.01.44.003A B05M Bottom Support, Bays #2 -> #4	8.00	EA	156,346	33,241	7,584	0	0	1,288	198,459	24807.42
01.06.01.44.003A B05N Gout Supports Plates	80.00	EA	13,636	2,899	661	0	0	112	17,308	216.36
01.06.01.44.003A B05P Set Floating Bulkheads, B #4->#2	2.00	EA	1,358	289	66	0	0	11	1,724	861.79
01.06.01.44.003A C01A Pump out Water, Bays #1 -> #4	560200.00	GAL	14,394	3,060	698	0	0	119	18,272	0.03
01.06.01.44.003A C01A BULKHEAD - STAGE 3										
01.06.01.44.003A C05C End & Side Support, Bays #7 & #4	1.00	EA	203,939	43,360	9,892	0	0	1,680	258,871	129435.61

LABOR ID: EMAS96

EQUIP ID: NAT95A

Currency in DOLLARS

CREW ID: NAT94B

UPB ID: NAT95A

Sat 07 Sep 1996  
Eff. Date 06/20/96

PROJECT INFL16: U.S. Army Corps of Engineers  
Eight Spillway Deflectors Bulkhead - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96, "DM's Bulkhead  
\*\* PROJECT INDIRECT SUMMARY - CSI ITEM \*\*

TIME 01:08:17  
SUMMARY PAGE 2

	QUANTITY	UOM	TOTAL DIRECT	FOOH	HOON	PROF	PL & PD	BOND	TOTAL COST	UNIT COST
01.06.01.44.003A C05F	1.00	EA	55,093	11,713	2,672	0	0	454	69,933	69932.88
01.06.01.44.003A C05I	8.00	EA	156,346	33,241	7,584	0	0	1,288	198,459	24807.42
01.06.01.44.003A C05N	72.00	EA	12,272	2,609	595	0	0	101	15,578	216.36
01.06.01.44.003A C05P	2.00	EA	1,358	289	.66	0	0	0	1,724	861.79
01.06.01.44.003A C05R	560200.00	GAL	14,394	3,060	698	0	0	119	18,272	0.03
TOTAL DEMATERING IN FRONT OF SPILLWAY	3.00	EA	1,401,143	297,899	67,962	0	0	11,545	1,778,550	592849.93
01.06.01.44.003B UNWATERING IN FRONT OF SPILLWAY										
01.06.01.44.003B A01A	1.00	EA	3,487	741	169	0	0	0	4,426	2212.86
01.06.01.44.003B A05C	2.00	EA	2,031	432	99	0	0	29	2,578	1289.07
01.06.01.44.003B A05F	2.00	LF	6,150	1,308	298	0	0	17	7,807	7807.12
01.06.01.44.003B A05I	8.00	EA	19,061	4,053	925	0	0	51	24,195	3024.36
01.06.01.44.003B A05M	6.00	EA	3,250	691	158	0	0	157	4,126	687.62
01.06.01.44.003B A05P	290.00	EA	130,488	27,743	6,329	0	0	1,075	165,635	571.16
01.06.01.44.003B A05Q	1.00	EA	3,487	741	169	0	0	0	4,426	2212.86
01.06.01.44.003B B01A	2.00	EA	4,375	930	212	0	0	29	5,553	2776.46
01.06.01.44.003B B05C	2.00	EA	6,150	1,308	298	0	0	36	7,807	7807.12
01.06.01.44.003B B05F	8.00	EA	19,061	4,053	925	0	0	51	24,195	3024.36
01.06.01.44.003B B05I	6.00	EA	3,250	691	158	0	0	157	4,126	687.62
01.06.01.44.003B B05M	290.00	EA	130,488	27,743	6,329	0	0	1,075	165,635	571.16
01.06.01.44.003B B05P	1.00	EA	3,487	741	169	0	0	0	4,426	2212.86
01.06.01.44.003B B05Q	2.00	EA	20,425	4,343	991	0	0	29	25,927	12963.39
01.06.01.44.003B C01A	1.00	EA	3,281	698	159	0	0	168	4,165	4164.69
01.06.01.44.003B C05C	8.00	EA	19,061	4,053	925	0	0	27	24,195	3024.36
01.06.01.44.003B C05F	6.00	EA	2,167	461	105	0	0	157	2,750	457.62
01.06.01.44.003B C05I	374.00	EA	168,284	35,779	8,163	0	0	1,387	213,613	571.16
TOTAL UNWATERING IN FRONT OF SPILLWAY	3.00	EA	547,982	116,507	26,580	0	0	4,515	695,584	231861.39
01.06.01.44.003C BULKHEAD SPILLWAY CONCR REMOVAL										
01.06.01.44.003C 01AE	29.00	EA	28,606	6,082	1,388	0	0	236	36,311	1252.10
01.06.01.44.003C 01BC	34.00	EA	57,278	12,178	2,778	0	0	472	72,707	2138.43
01.06.01.44.003C 01CA	208.00	CY	26,513	5,637	1,286	0	0	218	33,655	161.80
01.06.01.44.003C 01ED	208.00	CY	648	138	31	0	0	5	823	3.96
TOTAL BULKHEAD SPILLWAY CONCR REMOVAL	160.00	CY	113,046	24,035	5,483	0	0	931	143,495	896.85
01.06.01.44.003E RETROFIT FLOATING BULKHEAD										
01.06.01.44.003E 05AA	5750.00	SF	2,284	486	111	0	0	19	2,899	0.50
01.06.01.44.003E 06AA	360.00	LF	36,854	7,836	1,788	0	0	304	46,781	129.95

LABOR ID: EWAS96

EQUIP ID: NAT95A

CREW ID: NAT94B

UPB ID: NAT95A

Currency in DOLLARS

Sat 07 Sep 1996  
Eff. Date 06/20/96

PROJECT INFL16: U.S. Army Corps of Engineers  
Eight Spillway Deflectors Bulkh. - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96 "DW's Bulthead"  
\*\* PROJECT INDIRECT SUMMARY - CSI ITEM \*\*

TIME 01:08:17  
SUMMARY PAGE 3

		QUANTITY UOM	TOTAL DIRECT	FOOH	HOOH	PROF	PL & PD	BOND	TOTAL COST	UNIT COST
01.06.01.44.003E_09AA	Paint System No.3-A-Z,Vinyl Zinc	5750.00 SF	14,957	3,180	725	0	0	123	18,986	3.30
TOTAL RETROFIT FLOATING BULKHEAD		2.00 EA	54,095	11,501	2,624	0	0	446	68,666	34333.16
01.06.01.44.004-	SPILLWAY CONCRETE REMOVAL									
01.06.01.44.004-S00-	SPILLWAY CONCRETE REMOVAL	1.00 TT	0	0	0	0	0	0	0	0.01
01.06.01.44.004-S01A	6"Sawcut Spillway Concrete Slope	300.00 LF	28,851	6,134	1,399	0	0	238	36,623	122.08
01.06.01.44.004-S01B	Demo of Spillway Upper Concrete	90.00 CY	10,521	2,237	510	0	0	87	13,355	148.39
01.06.01.44.004-S01D	Load, Barge & Unload Conc.Debri's	120.00 CY	5,551	1,180	269	0	0	46	7,046	58.72
01.06.01.44.004-S01F	Load,Haul & Disposal Conc.Debri's	120.00 CY	1,945	414	94	0	0	16	2,469	20.58
TOTAL SPILLWAY CONCRETE REMOVAL		90.00 CY	46,869	9,965	2,273	0	0	386	59,493	661.04
01.06.01.44.005-	REBAR DOWEL INSTALLATION									
01.06.01.44.005-C00-	PIER EXTENSION DOWEL INSTALLATN	1.00 TT	0	0	0	0	0	0	0	0.01
01.06.01.44.005-C01B	PE-Placing &Remov Dowel Template	7.00 EA	10,880	2,313	528	0	0	90	13,811	1973.02
01.06.01.44.005-C02D	PE-Drilling #11 Dowel Holes	1960.00 LF	56,579	12,029	2,744	0	0	466	71,819	36.64
01.06.01.44.005-C03F	PE-Placing #11 Rebar Dowels	280.00 EA	12,730	2,706	617	0	0	105	16,158	57.71
01.06.01.44.005-C04H	PE-Clean & Grout Rebar Dowels	280.00 EA	54,510	11,589	2,644	0	0	449	69,193	247.12
01.06.01.44.005-C04J	PE-Remove Rebar Dowels Packers	280.00 EA	5,309	1,129	258	0	0	44	6,739	24.07
01.06.01.44.005-L00-	LOWER DEFLECTOR DOWEL INSTALLATN	1.00 TT	0	0	0	0	0	0	0	0.01
01.06.01.44.005-L01B	LWD-PlacingRemov Dowel Template	6.00 EA	18,374	3,906	891	0	0	151	23,323	3887.12
01.06.01.44.005-L02D	LWD-Drilling #11 Dowel Holes	4536.00 LF	135,663	28,844	6,580	0	0	1,118	172,205	37.96
01.06.01.44.005-L03F	LWD-Placing #11 Rebar Dowels	648.00 EA	34,670	7,371	1,882	0	0	286	44,009	67.92
01.06.01.44.005-L04H	LWD-Clean & Grout Rebar Dowels	648.00 EA	120,012	25,516	5,821	0	0	989	152,338	235.09
01.06.01.44.005-M00-	UPPER DEFLECTOR DOWEL INSTALLATN	1.00 TT	0	0	0	0	0	0	0	0.01
01.06.01.44.005-M01B	UPD-PlacingRemov Dowel Template	6.00 EA	515	110	25	0	0	4	654	109.04
01.06.01.44.005-M02D	UPD-Drilling #11 Dowel Holes	1134.00 LF	27,420	5,830	1,330	0	0	226	34,806	30.69
01.06.01.44.005-M03F	UPD-Placing #11 Rebar Dowels	162.00 EA	5,635	1,198	273	0	0	46	7,152	44.15
01.06.01.44.005-M04H	UPD-Clean & Grout Rebar Dowels	162.00 EA	38,633	8,214	1,874	0	0	318	49,039	302.71
TOTAL REBAR DOWEL INSTALLATION		82810.00 LB	520,931	110,756	25,267	0	0	4,292	661,246	7.99
01.06.01.44.006-	SPILLWAY CONCRETE PLACEMENT									
01.06.01.44.006-A00-	TESTING OF SURFACE FINISH	1.00 TT	0	0	0	0	0	0	0	0.01
01.06.01.44.006-A03A	TI-Concrete Placement & Finish	3.00 CY	2,029	431	98	0	0	17	2,575	858.48
01.06.01.44.006-A03D	TI-Forms & Earthwork	400.00 SF	5,245	1,115	254	0	0	43	6,658	16.64
01.06.01.44.006-G00-	PIER EXTENSION CONCRETE	1.00 TT	0	0	0	0	0	0	0	0.01
01.06.01.44.006-G03A	PE-Concrete Prep	2100.00 SF	4,405	937	214	0	0	36	5,592	2.66
01.06.01.44.006-G03D	PE-Misc Forms Placement Items	12.60 TON	36	8	2	0	0	45	28,505	2262.32
01.06.01.44.006-G03G	PE-Rebar Placement	490.00 CY	22,456	4,774	1,089	0	0	185	28,505	2262.32
01.06.01.44.006-G03K	PE-Concrete Placement & Finish	1.00 TT	68,532	14,571	3,324	0	0	565	86,992	177.53
01.06.01.44.006-L00-	LOWER DEFLECTOR MASS CONCRETE	1.00 TT	0	0	0	0	0	0	0	0.01
01.06.01.44.006-Q03A	LWD-Concrete Prep	2790.00 SF	5,306	1,128	257	0	0	44	6,735	2.41
01.06.01.44.006-Q03D	LWD-Misc Forms Placement Items	1.00 TT	421	90	20	0	0	3	535	2.41

LABOR ID: EWAS96

Currency in DOLLARS

CREW ID: NAT94B

UPB ID: NAT95A

Sat 07 Sep 1996  
Eff. Date 06/20/96

U.S. Army Corps of Engineers

PROJECT INFL16: Eight Spillway Deflectors Bulkh. - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96, "DM's Bulkhead"

\*\* PROJECT INDIRECT SUMMARY - CSI ITEM \*\*

TIME 01:08:17

SUMMARY PAGE 4

	QUANTITY	UOM	TOTAL DIRECT	FOOH	HOOH	PROF	PL & PD	BOND	TOTAL COST	UNIT COST
01.06.01.44.006-003E LMD-Joint F Expansion Joint	750.00	SF	7,247	1,541	351	0	0	60	9,199	12.26
01.06.01.44.006-003G LMD-Rebar Placement	23.40	TON	37,777	8,032	1,832	0	0	311	47,953	2049.25
01.06.01.44.006-003K LMD-Concrete Placement & Finish	960.00	CY	148,433	31,559	7,200	0	0	1,223	188,415	196.27
01.06.01.44.006-000- MID DEFLECTOR CONCRETE CURVE	1.00	TT	0	0	0	0	0	0	0	0.01
01.06.01.44.006-003A MDD-Concrete Prep	750.00	SF	2,492	530	121	0	0	21	3,163	4.22
01.06.01.44.006-003C MDD-Misc Form Placement Items	600.00	SF	11,231	2,388	545	0	0	93	14,256	5.09
01.06.01.44.006-003D MDD-Upper End Side Forms	13.80	TON	2,408	512	117	0	0	20	3,056	2312.36
01.06.01.44.006-003G MDD-Rebar Placement	300.00	CY	25,139	5,345	1,219	0	0	207	31,911	502.13
01.06.01.44.006-000- UPPER DEFLECTOR CONCRETE CURVE	1.00	TT	118,673	25,231	5,756	0	0	978	150,638	3.98
01.06.01.44.006-003A UPD-Concrete Prep	1290.00	SF	0	0	0	0	0	0	0	3.98
01.06.01.44.006-003D UPD-Side Forms Placement	1546.00	SF	4,049	861	196	0	0	33	5,139	71.05
01.06.01.44.006-003G UPD-Rebar Placement	7.20	TON	86,535	18,398	4,197	0	0	713	109,843	2243.08
01.06.01.44.006-003K UPD-Concrete Placement & Finish	120.00	CY	12,723	2,705	617	0	0	105	16,150	524.63
01.06.01.44.006-003L UPD-Plug Anchor Bolt Holes	144.00	EA	49,596	10,545	2,406	0	0	409	62,955	2.391
TOTAL SPILLWAY CONCRETE PLACEMENT	1870.00	CY	1,884	400	91	0	0	16	2,391	16.60
01.06.01.44.006A SPILLWAY CONCRETE FORMS			616,617	131,100	29,909	0	0	5,081	782,706	418.56
01.06.01.44.006A_03AC Front Forms Placement	7920.00	SF	372,568	79,212	18,071	0	0	3,070	472,922	59.71
TOTAL SPILLWAY CONCRETE FORMS	7920.00	SF	372,568	79,212	18,071	0	0	3,070	472,922	59.71
01.06.01.44.006B SPILLWAY PIER CONCRETE FORMS										
01.06.01.44.006B_03AC Front Forms Placement	1890.00	SF	157,620	33,512	7,645	0	0	1,299	200,076	105.86
01.06.01.44.006B_03AD Side Forms Placement	2472.00	SF	197,157	41,918	9,563	0	0	1,625	250,263	101.24
TOTAL SPILLWAY PIER CONCRETE FORMS	6.00	EA	354,777	75,430	17,208	0	0	2,923	450,339	75056.42
01.06.01.44.006C SPILLWAY GROUT MISC BLOCKOUT										
01.06.01.44.006C_03AN Grouting 16x16 Placement	3.00	CY	14,739	3,134	715	0	0	121	18,708	6236.15
TOTAL SPILLWAY GROUT MISC BLOCKOUT	3.00	CY	14,739	3,134	715	0	0	121	18,708	6236.15
01.06.01.44.007- REMOVE FLTNG PLANT EMERGENCY SP										
01.06.01.44.007-01AB Mobilization Floating Plant	4.00	EA	100,160	5,173	4,213	0	0	1,248	110,795	27698.83
01.06.01.44.007-010E DEWATER SPILLWAY GATES U-Stream	1.00	TT	0	0	0	0	0	0	0	0.01
01.06.01.44.007-010F Install & Remov Spillway Stoplog	4.00	SET	38,102	1,095	1,568	0	0	498	41,263	10315.78
TOTAL REMOVE FLTNG PLANT EMERGENCY SP	2.00	EA	138,262	6,269	5,781	0	0	1,746	152,058	76029.22
01.06.01.44.008- STANDBY TIME DURING EMERGENCY SP										

LABOR ID: EWAS96

EQUIP ID: NAT95A

Currency in DOLLARS

CREW ID: NAT94B

UPB ID: NAT95A

Sat 07 Sep 1996  
Eff. Date 06/20/96

U.S. Army Corps of Engineers  
PROJECT IHFL16: Eight Spillway Deflectors Bulkhead - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96, "DPM's Bulkhead"  
\*\* PROJECT INDIRECT SUMMARY - CSI ITEM \*\*

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SUMMARY PAGE 5

	QUANTITY	UOM	TOTAL DIRECT	FOOH	HOCH	PROF	PL & PD	BOND	TOTAL COST	UNIT COST
01.06.01.44.008_01AB	Standby Time During Emergency	100.00 HR	85,523	2,459	3,519	0	0	1,117	92,619	926.19
TOTAL STANDBY TIME DURING EMERGENCY SP										
		100.00 HR	85,523	2,459	3,519	0	0	1,117	92,619	926.19
01.06.01.44.009- SPILLBAYS 2 & 9 (OPTIONAL WORK)										
01.06.01.44.009- 100- LOWER DEFLECTOR DOWEL INSTALLATION		1.00 TT	0	0	0	0	0	0	0	0.02
01.06.01.44.009- 101B LWD-Placing & Removing Dowel Template		2.00 EA	5,301	2,423	386	0	0	89	8,199	4099.61
01.06.01.44.009- 102D LWD-Drilling #11 Dowel Holes		1512.00 LF	49,484	22,616	3,605	0	0	835	76,540	50.62
01.06.01.44.009- 103F LWD-Placing #11 Rebar Dowels		216.00 EA	12,977	5,931	945	0	0	219	20,072	92.93
01.06.01.44.009- 104H LWD-Clean & Grout Rebar Dowels		216.00 EA	40,004	18,284	2,914	0	0	675	61,877	286.47
01.06.01.44.009- 100- UPPER DEFLECTOR DOWEL INSTALLATION		1.00 TT	0	0	0	0	0	0	0	0.02
01.06.01.44.009- 102D UPD-Drilling #11 Dowel Holes		378.00 LF	12,308	5,626	897	0	0	208	19,038	50.37
01.06.01.44.009- 103F UPD-Placing #11 Rebar Dowels		54.00 EA	2,406	1,100	175	0	0	41	3,722	68.93
01.06.01.44.009- 104H UPD-Clean & Grout Rebar Dowels		54.00 EA	12,878	5,886	938	0	0	217	19,919	368.86
01.06.01.44.009- 100- DEMATER SPILLWAY GATES D-Stream		1.00 TT	0	0	0	0	0	0	0	0.02
01.06.01.44.009- 101F Install & Remove Spillway Stoplog		2.00 SET	24,936	11,397	1,817	0	0	421	38,571	19285.25
01.06.01.44.009- 101G Cost to Operate Sump Pump		2.00 SET	617	282	45	0	0	10	954	476.92
01.06.01.44.009- 100- DEVATERING IN FRONT OF SPILLWAY		1.00 TT	0	0	0	0	0	0	0	0.02
01.06.01.44.009- 100- LOWER DEFLECTOR MASS CONCRETE		1.00 TT	0	0	0	0	0	0	0	0.02
01.06.01.44.009- 100- LWD-Concrete Prep		930.00 SF	1,705	779	124	0	0	29	2,638	2.84
01.06.01.44.009- 103A LWD-Misc Forms Placement Items		250.00 SF	140	64	10	0	0	2	217	14.95
01.06.01.44.009- 103E LWD-Joint F Expansion Joint		7.80 TON	12,811	1,104	176	0	0	41	3,736	2540.53
01.06.01.44.009- 103G LWD-Rebar Placement		320.00 CY	49,478	5,855	933	0	0	216	19,816	239.16
01.06.01.44.009- 103K LWD-Concrete Placement & Finish		1.00 TT	0	0	0	0	0	834	76,531	0.02
01.06.01.44.009- 100- SAWCUT SPILLWAY CONCRETE REMOVAL		100.00 LF	9,707	4,437	707	0	0	164	15,015	150.15
01.06.01.44.009- 101A Demo of Spillway Upper Concrete		30.00 CY	3,507	1,603	255	0	0	59	5,424	180.81
01.06.01.44.009- 101B Load, Barge & Unload Conc.Debris		40.00 CY	1,850	846	135	0	0	31	2,862	71.55
01.06.01.44.009- 101F Load, Haul & Disposal Conc.Debris		40.00 CY	648	296	47	0	0	11	1,003	25.08
01.06.01.44.009- 100- MID DEFLECTOR CONCRETE CURVE		1.00 TT	0	0	0	0	0	0	0	0.02
01.06.01.44.009- 103A MDD-Concrete Prep		250.00 SF	934	427	68	0	0	16	1,445	5.78
01.06.01.44.009- 103C MDD-Misc Form Placement Items		200.00 SF	3,744	1,711	273	0	0	63	5,790	6.21
01.06.01.44.009- 103G MDD-Upper End Side Forms		4.60 TON	8,803	367	58	0	0	14	1,241	2817.71
01.06.01.44.009- 103K MDD-Rebar Placement		100.00 CY	39,558	3,830	610	0	0	141	12,961	611.86
01.06.01.44.009- 100- UPPER DEFLECTOR CONCRETE CURVE		1.00 TT	0	0	0	0	0	667	61,186	0.02
01.06.01.44.009- 103A UPD-Concrete Prep		430.00 SF	1,246	569	91	0	0	21	1,927	4.48
01.06.01.44.009- 103G UPD-Rebar Placement		2.40 TON	4,241	1,938	309	0	0	72	6,560	2733.28
01.06.01.44.009- 103K UPD-Concrete Placement & Finish		40.00 CY	16,532	7,556	1,204	0	0	279	25,571	639.28
01.06.01.44.009- 103L UPD-Plug Anchor Bolt Holes		48.00 EA	752	344	55	0	0	13	1,163	24.24
TOTAL SPILLBAYS 2 & 9 (OPTIONAL WORK)										
		2.00 EA	319,364	145,964	23,266	0	0	5,386	493,980	246990.18
TOTAL FISHWAYS AND FISH LADDERS										
		8.00 EA	4,795,809	1,058,857	238,840	0	0	43,291	6,136,797	767099.64
TOTAL FISH FACILITIES AT DAMS										
		1.00 EA	4,795,809	1,058,857	238,840	0	0	43,291	6,136,797	6136797
TOTAL FISH AND WILDLIFE FACILITIES										
		1.00 EA	4,795,809	1,058,857	238,840	0	0	43,291	6,136,797	6136797

LABOR ID: EWAS96 EQUIP ID: NAT95A

Currency in DOLLARS

CREW ID: NAT948 UPB ID: NAT95A

Sat 07 Sep 1996  
Eff. Date 06/20/96

PROJECT IHFL16: U.S. Army Corps of Engineers  
Eight Spillway Deflectors Bulkh. - Ice Harbor Lock & Dam  
After Bid Estimate 9/6/96 "DW" 's Bulkhead  
\*\* PROJECT INDIRECT SUMMARY - CSI ITEM \*\*

TIME 01:08:17  
SUMMARY PAGE 6

	QUANTITY	UOM	TOTAL DIRECT	FOOH	HOOH	PROF	PL & PD	BOND	TOTAL COST	UNIT COST
TOTAL CONSTRUCT SPILLWAY DEFLECTOR	8.00	EA	4,795,809	1,058,857	238,840	0	0	43,291	6,136,797	767099.64
TOTAL Eight Spillway Deflectors Bulkh.	8.00	EA	4,795,809	1,058,857	238,840	0	0	43,291	6,136,797	767099.64
CONTINGENCY									70,938	8867.28
TOTAL INCL OWNER COSTS									6,207,735	775966.92

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LABOR ID: EH4596 EQUIP ID: NAT95A

Currency in DOLLARS

CREW ID: NAT948 UPB ID: NAT95A